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COLLEGE OF ARTS AND SCIENCES

ELEMENTAL COMPOSITION, SOURCE TRACKING, AND AIR QUALITY ASSESSMENT OF PM2.5 AND PM10 POLLUTION IN QATAR

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ABSTRACT

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Title: Elemental Composition, Source Tracking, and Air Quality Assessment of PM2.5 and PM10 Pollution in Qatar

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Particulate matter (PM) pollution is one of the major environmental pollution issues severely affecting human health and air quality all over the world. Based on the recent World Health Organization (WHO) report, PM levels were considered relatively high in Qatar. This might mainly be attributed to arid climate, but also due to rapid industrialization and urbanization as well as traffic. The literature on PM pollution and its source is limited in Qatar and the region. Therefore, this study was carried out to assess the air quality based on PM2.5 and PM10 levels at different locations in Qatar, determine the elemental composition of PM2.5 and PM10 to trace their sources, and create a map by using Geographical Information System (GIS) to show the air quality based on PM levels in select locations in Qatar.

A total of 100 samples (60 for PM2.5 and 40 for PM10) were collected using SKC Deployable Particulate Sampler (DPS) System for 24-hr during the months of September to December, 2016. The sampling was conducted at five different locations, namely, Qatar University (QU), Education City (EC), Aspire Zone (AZ), Whole Sale Market area (WM), and Al-Wakrah City (AW). The elemental composition of PM samples was determined using an inductively coupled plasma optical emission spectrometry (ICP-OES). The

relationship between the environmental conditions and PM levels were also established.

The health risks associated with different PM levels were calculated using the US EPA Air Quality Index (AQI) tool. The AQI values calculated based on the daily concentrations of PM2.5 and PM10 at each sampling location were computed on maps using GIS modeling system in combination with Google Earth.

The overall mean concentrations of 24-hr PM2.5 ranged from 50 $\mu g/m^3$ to 64 $\mu g/m^3$, while PM10 levels were between 127 $\mu g/m^3$ and 185 $\mu g/m^3$. The four months mean concentrations of PM2.5 were determined to be 50, 64, 55, 59, and 57 $\mu g/m^3$ at QU, EC, AZ, WSM, AW, respectively. The average 24-hr PM10 levels were 138 $\mu g/m^3$ at QU, 156 $\mu g/m^3$ at EC, 127 $\mu g/m^3$ at AZ, 185$\mu g/m^3$ at WM, and 160 $\mu g/m^3$ at AW. The concentrations of PM2.5 detected at each station exceeded the WHO guideline (20 $\mu g/m^3$) by 2.5 to 3 fold during the study period.

The presence of high concentrations of Ca, Fe, Al, Fe, Sr, Mn, Na, and Mg indicated the major sources of PM to be soil/crustal. The identification of Ni, Co, Cr, Cd, Ba, Pb, V, and Zn were directly related to anthropogenic sources, specifically due to fossil fuel combustion and vehicular emission and these levels were reported at the highest levels at the wholesale market station. The AQI levels determined at all stations indicated that overall air quality at Qatar University and Aspire Zone area was considered to be “Moderate” for PM10 and “Unhealthy for sensitive group” for PM2.5 levels. While Education City, Whole sale Market, and Al-Wakrah city areas had “unhealthy” and “unhealthy for sensitive group” ratings for PM2.5 and PM10 levels, respectively.

The statistical analysis on determining the effect of sampling date and locations on the concentration of PM2.5 and PM10 showed that there is a significant relationship ($p<0.01$) between PM levels, sampling stations, and sampling date.

These findings highlight the need for more research on PM pollution 1) to determine seasonal levels since this study only covered four months (September-December), 2) to better understand the source of PM pollution (in addition to elements, the levels of Poly Aromatic Hydrocarbons should also be determined), and 3) to establish more effective control measures to protect public health and preserve the environment in Qatar.

DEDICATION

I would like to dedicate my work to the residents of Qatar who need to know more about air quality.

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I would first like to thank my thesis advisor Prof. Ipek Goktepe in the Department of Biological and Environmental Sciences at Qatar University (QU) for her support, patience, and guidance during my master's degree. Thank you Prof. Ipek for your patience with me to finalize this work. You were really diligent in every step of the writing process I cannot thank you enough and will remember all your hard work and support forever. Special thanks to my committee members who were very helpful, supportive, and encouraging, special thanks and gratitude are for Dr. Konstantinos E. Kakosimos, who I consider as the first person to ask advice on air pollution field in Qatar; Dr. Perumal Balakrishnan who provided all the support and assistance needed to complete the maps and also advised me during my BSc graduation project; and Dr. Yousria Soliman Mohamed Elfaham for her guidance and advice in this master's thesis. Thanks to Ms. Israa El-Nemr who was the second hidden supervisor during my lab work. Thanks to the department, specifically the heads of the department who encouraged me to enter the bachelor's degree in Environmental Science, Dr. Hamda Al-Naimi and Dr. Samir Jaoua, who helped obtain the accreditation from CHES, Dr. Fatima Al-Naimi, who supported our batch in bachelor's degree to have training in Oman, and our new head of the department, Dr. Mohammad Al-Safran, who allowed me to work in the department laboratories to complete my thesis work. I would also like to thank Dr. Mohammed Abu-Dieyeh, the graduate coordinator, for his patience on all our inquiries about master's degree program and help in securing a Graduate Teaching Assistantship in the department.

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CHAPTER I: INTRODUCTION

In the last few years, the State of Qatar has been going through many changes and developments in the economy, urban environments, and construction. The population of Qatar is rapidly growing, reaching 2,668,415 according to the latest statistics. This figure is expected to increase to three million by 2026 (MDPS, 2017). The fast population growth caused many environmental changes. Qatar's National Vision 2030 was developed to address these environmental changes by establishing a balance between economic growth, social development, and environmental protection. The vision emphasizes sustaining the environment for the future generations by balancing between developmental needs and the protection of the natural environment, land, sea, and air (Sillitoe, 2014).

As a result of this initiative, air quality research field has received much needed attention from researchers in Qatar as well as around the world. There is now a substantial body of epidemiological evidence that establishes a link between exposure to air pollution and increased mortality (especially premature death) and morbidity due to a wide range of adverse cardiovascular and respiratory problems (Lee et al., 2014).There are various pollutants in the air, such as nitrogen oxides (NOx), sulfur oxides (SOx), ozone (O_3), particulate matter (PM), CO, CO_2, hazardous air pollutants (e.g., aldehydes, PAHs, etc.).

Particulate matter are fine particles that are suspended in the air and originate from different sources (Laden et al., 2000), including natural and anthropogenic sources (EPA, 2015). Natural sources include wind-blown desert dust, sea spray aerosols, volcanoes, seismic activity, and wild fires (EPA, 2015; Putaud et al., 2004). Examples of anthropogenic sources include vehicle emissions from fuel combustion, domestic heating, incineration, construction and emissions from thermal power generation (EEA, 2015; Hassan et al., 2016). The major size distribution of PM is between 2.5 and 10 μm (PM2.5 and PM10) (Khan et al., 2010). PM2.5 sources are mainly dust/soil, oil combustion, petrochemical industries, and traffic emissions (Brow et al., 2013). In contrast, PM10 mainly comes from natural sources and transportation (Lenschow et al., 2001).

Many studies have investigated the effects of different sizes of PM and their impact on human health (Davidson et al., 2005). Several health problems result from PM exposure, like respiratory and cardiovascular morbidity, asthma and other respiratory symptoms, and mortality related to lung cancer (Brook et al., 2010; Chen et al., 2016). The sources of PM can be identified based on the chemical and physical properties of these pollutants and their reactions with other chemicals suspended in the air (Ye et al., 2017). The health effects depend on the exposure time and doses (Shaughnessy et al., 2015). The effects also depend on the concentration of PM (PM2.5, PM10; unit mass/m^3), the PM's complex compositions of trace metals and other elements. Therefore, it is important to identify the probable source of PM promptly.

The Middle East is considered one of the most polluted areas in terms of PM pollution (Elbayoumi et al., 2013). Rapid urbanization and construction in this region have created concerns about rising health problems related to PM pollution (Tsiouri et al., 2015). Factors that affect the dispersion and concentration of PM include temperature, humidity, the height of the mixing layer, and pressure (Khan et al., 2010; Marcazzan et al., 2001). Qatar is located in an arid region with desert features similar to other Middle

Eastern countries. The World Health Organization (WHO) has reported high levels of PM2.5 and PM10 in this area (WHO, 2016).

Since Qatar is a fast developing nation, air pollution issues related to PM pollution need urgent attention. Therefore, this study was carried out to monitor the concentrations of PM (PM2.5 and PM10) at different locations in Qatar by integrating emissions within a framework based on a geographic information system (GIS) using different modeling techniques. The study also aimed at investigating the air quality based on PM concentrations and elemental compositions of PM to identify the main source at these sampling sites. The results obtained in this study could be helpful to protect public health and the environment in Qatar.

CHAPTER II: LITERATURE REVIEW

Air pollution problem has become an important public health issue as a result of massive population increases and industrial development (Loupa et al., 2016). Numerous air pollution studies offer indications relating diverse effects and diseases to the toxic substances present in air pollutants (Vallero, 2014). Air pollution in urban areas considered as significant problem, especially in developing countries (Mage et al., 1996). The World Health Organization (WHO) conducted a study on air pollution in 1958 which showed that scientists need to focus deeply on air pollution and its effects on humans, organisms, and earth systems (WHO, 2016). Specific studies carried out during the twentieth century have focused on acid rain in European counties and the United States (Patel et al., 1974; Schindler, 1988). Acid rain is a common type of pollution in many developed countries and can affect people' lives. However, acid rain is not a global issue, but there are other global air pollution problems that are occurring in tropical and desert countries. In the last part of the twentieth century, scientists started to understand the composition of air pollution, which opened up more opportunities to investigate air pollution in a wider view and to investigate more details by combining sources with other factors (Vallero, 2014).

Air pollution is caused by a mixture of complex components of solids and liquids that vary in size, composition, and origin (natural and anthropogenic) (Dockery et al., 1993; Samet et al., 2002; Brook, et al., 2004). The anthropogenic sources are made by people through automobiles, industry, construction, etc. In contrast, natural sources are mainly from dust, volcanoes, and forest fires, etc. (Kampa & Castanas, 2008). Current scientific evidence proves the fact that outdoor air pollution causes a variety of diseases, such as respiratory illnesses, cardiovascular illnesses, and death. One of the major air pollutants considered to be the most detrimental to human health is particulate matter (PM).

1.1. Particulate Matter

Particulate matter (PM) are a mixture of solid and liquid particles that are organic and inorganic chemicals (Jang et al., 1997; Laden et al., 2000). Anthropogenic sources that are most dominant in urban areas include industrial fuel combustion, domestic heating in houses, fuel burned by vehicles, road wear, and other sources (EEA, 2015). The elemental composition of PM depends on the source. For example, the elements commonly found in PM generated by power plants are nickel, zinc, sulfate, and mineral aerosol (sodium, magnesium, chloride). Sources including vehicles emit elements such as trace elements, and nitrate, elemental/organic carbon (Rodríguez et al., 2004). Toxic heavy metals like Cd, Pb, Cr, Zn, Ni, and As are usually emitted by the metal industry, and Al, Si, K, Ti, and Fe are distributed by coal combustion. Al and Fe are the main crustal elements that used to be compared with other elements to identify possibility of anthropogenic sources. PM with significant fractions of Si, Cl, and Fe mainly come from burning biomass (Rodríguez et al., 2004). Elements like Na, Cl, and Mg are mainly form sea spray and sea salts (Viana et al., 2008).

There are six criteria air pollutants listed by the United States Environmental Protection Agency (USEPA) under the National Ambient Air Quality Standards (NAAQS) for Clean Air Requirement (USEPA, 2016). These air pollutants are ground-level ozone, PM, CO, lead, sulfur dioxide, and nitrogen dioxide. These pollutants were chosen based on their human health effects and the environmental damage they cause. The Ministry of Environment and Municipality in Qatar uses the same standards as listed by the USEPA with different pollution levels near the surrounding countries' levels (Tsiouri et al., 2015). The concentration limits of PM10 for 24 hours is 150 $\mu g/m^3$ and 50 $\mu g/m^3$ a year, which stays within the limit of other Middle East countries. For PM2.5 limits, the criteria set by the WHO is 50 $\mu g/m^3$ for 24 hours and 20 $\mu g/m^3$ annually, but in Qatar, there is no standard limit for PM2.5 (Table 1).

Table 1

Ambient air pollution limits in Qatari Environment Protection Law 30 (2002) and World Health Organization (WHO, 2005)

		Concentration averaged over							
		1 hour		**8 hours**		**24 hours**		**1 year**	
Pollutant	**Unit**	Qatar	WHO	Qatar	WHO	Qatar	WHO	Qatar	WHO
Nitrogen dioxide (NO2)	µg/m^3	400	200			150		100	40
Particulate Matter <10 µm	µg/m^3					150	50	50	20
Particulate Matter <2.5 µm	µg/m^3						25		10
Carbon Monoxide (CO)	mg/m^3	40	30	10	10				
Ground Level Ozone (O3)	µg/m^3	235		120	100				
Sulfur dioxide (SO_2)	µg/m^3					365	20	80	

The most recent report on air pollution published by WHO (WHO, 2016) mentioned Qatar as one of the most polluted countries in terms of PM10 and PM2.5 levels (Table 2).

The reported values were based on the official reported results, satellites data and modelling.

Table 2

World Health Organization's report on PM levels in Qatar (WHO, 2016)

Country	PM2.5 [μg/m³], Urban and rural areas			PM2.5 [μg/m³], Urban areas		
	Median	Lower	Upper	Median	Lower	Upper
Qatar	103	67	160	105	69	159

1.2. Size Distribution of Airborne Particulate Matter

Particulate matter are categorized into three sizes relying on their aerodynamic diameter (10, 2.5, and 1 μm). PM10 which is also called inhalable coarse particles (<2.5-<10μm), can be found near roadways and dusty industries and have short lifetime in atmosphere compared to PM2.5. PM10 stays in the air for minutes to days and travel distance of less than one to hundreds Km (Joint & World Health, 2006) . Common sources of PM10 are dust resuspension, mining, sea spray, construction, and demolition. PM2.5, which became the most studied pollution in the last ten years, was added to the air quality criteria because of its detrimental health effects on the respiratory system. It is called fine particles, with diameter less than 2.5 micrometer (<2.5). PM2.5 can travel long distances of up to 10^6 kilometers with ling lifetimes reaching days and weeks, and the main source of PM2.5 is bringing fossil fuel (organic biomass) and combustion process (Joint & World Health, 2006). It can be found in haze or smoke and is emitted directly from the source. Its size lets PM2.5 be inhaled deeper in the lings.

Particulate matter that less than1 μm in diameter are called PM1. It can be travel beyond the lungs disrupts systemic vascular function and causing significant health effects (Rundell et al., 2007). Its atmospheric half-life is minuets to hours and it can travel less than tens of kilometers (Joint & World Health, 2006). Composition and mass of particulate matter could be divided to main two categories which are fine and coarse particles. Particulate matter that are fine and coarse fractions are demonstrated in Figure 1.

Understanding the land use around the sampling station considered important in air pollution studies. Geographical information system software support researchers to build graphical display of geographical information to be presented on maps. That visual tools are used to visualize data in term of numbers to build more clear decision support to the reality on geography map.

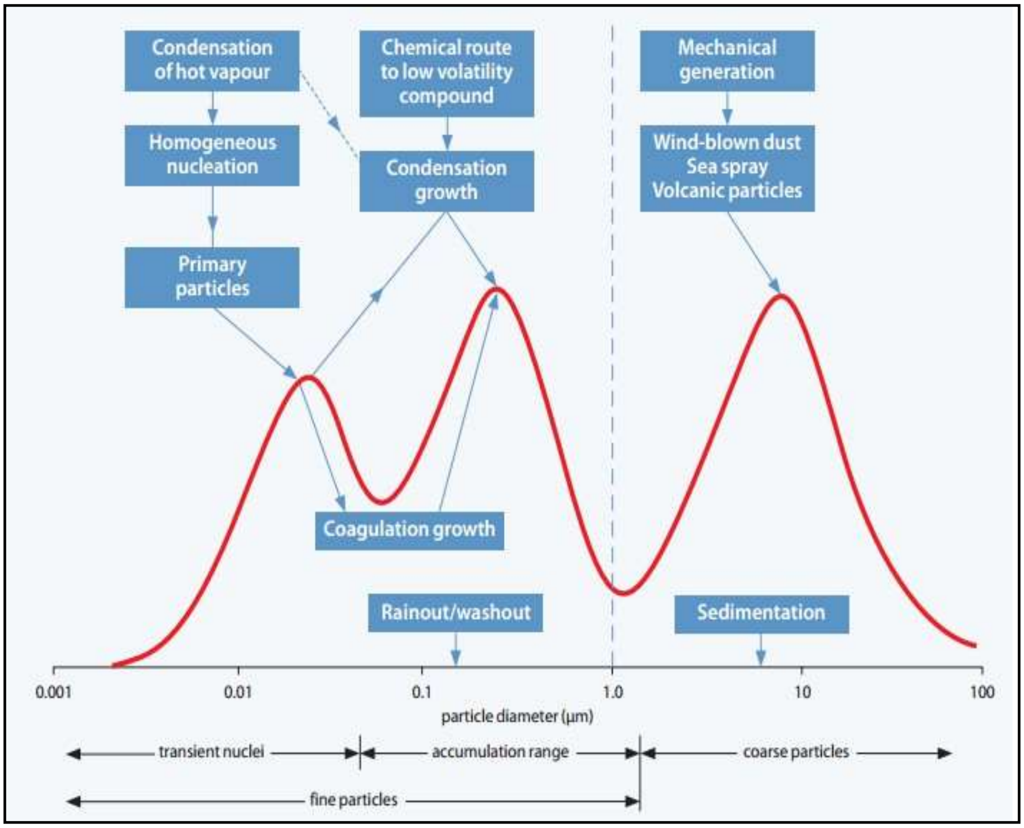

Figure 1. Size distribution of PM in ambient air (WHO, 2006).

1.3. PM Pollution Sources in Qatar

Increased urbanization, industrialization, and construction activities in Qatar have resulted in problems with air pollution (Tsiouri et al., 2015). Additionally, natural conditions such as dust storms often occur in the Arabian Gulf region are also contributing factors that directly impact air quality (Alam et al., 2014). Furthermore, the petroleum industry is the backbone of Arabian Gulf countries. The Qatar General Petroleum Corporation (QGPC) was established in 1974 (Bergendahl, 1985), and ranks as one of the largest petroleum and gas companies in the world. The recent industrial development in this region has led health organizations to establish a link between air pollution issues and petroleum industry activities (Chen et al., 2016). The total emissions of PM are mostly from natural sources, like ocean sprays, suspended dust from terrestrial areas, and burning fossil fuel. In a recent study by Hassan et al. (2016), it was found that the main source of particles size ranged between 0.25-32 µm were from wind erosion of the loose soil, where the study took place near to construction area. The limits of PM in Qatar and the Middle East were reviewed by Tsiouri et al. (2015) who reported that most of the countries in this region have higher PM limits than non-dusty countries due to the concentration levels being naturally high in this region (Table 3).

Table 3

Particulate matter (PM) standards established by USEPA, WHO, Qatar, and several Middle East Countries (Tsiouri et al., 2015)

Standards	**PM type and averaging time**			
	PM10 (μg/m^3)		PM2.5 (μg/m^3)	
	24-h	Annual	24-h	Annual
USEPA (EPA, 2010)	150	50	35	15
EU (EC, 2010)	50	40	-	25
WHO (WHO, 2006; WHO, 2011)	50	20	25	10
Jordan (Al-Zubi, 2011)	120	70	-	-
Kuwait (IES, 2011)	150	90	35	15
Lebanon (LEDO, 2001)	80	-	-	-
Oman (HMR, 2010)	150	-	35	15
Qatar (Abdel-Moati, 2008)	150 (1 h)	50 (3 month)	-	-
Saudi Arabia (PME, 2012)	340	80	35	15
Syria (ELARD, 2009)	100	-	-	-
UAE (EAD, 2014)	150	-	-	-

1.4 Anthropogenic Sources

1.4.1 Industrial Activities

Qatar has an area of 11,572.07 Km^2 and industrial cities are spread out in various locations for petroleum and chemical production. PM2.5 mainly originates from secondary pollutants (which react in the air), followed by primary pollutants (trace metals that could come from industry and transportation systems) which are mainly the sources of PM10 (Heal et al., 2012). Industrial and electrical power plants are recognized as the main stationary air pollution sources in urban cities. These sources are considered as point sources where the type of emission can be easily identified. In Qatar, there are two main power plants for electrical production with total production reaching 8000MW (QEWC, 2011). Elements like Ni, Cr, Cu, Sn, Zn, Mo, Sb, Pb, and Cd in PM could give indications industrial activities -including power plants- (Das et al., 2015).

Highlighting industrial sources depends on the results of sampling filters collected from sites. Based on official sources, there is no data available on PM sources from industrial activities in Qatar. Since high levels of PM2.5 come from anthropogenic sources such as industry and traffic, several stationary samplers are needed to have continuous readings for longer period near the sources and living areas.

1.4.2 Traffic

Qatar is considered as one of the richest countries in the world when it comes to capital income. Transportation systems in Qatar are mainly based on private cars, and using public transportation is not common in this country. There is no metro system yet, and public bus transportation is not convenient for middle income people since using private cars is faster. Furthermore, trucks are the main method for transporting goods due to the absence of freight trains. Particles generated by vehicle activities come from several processes, such as the combustion of fossil fuel, resuspension of road/soil dust, tire friction, and brake linings (Laschober et al., 2004). Fine particulate matter is not only from natural sources, it is also come from vehicles (Hassan et al., 2016). PM emitted from or related to traffic varies during periods of high traffic density with poor air movement in urban areas. For example, human exposure to traffic pollutants is higher in street canyons (Vardoulakis et al., 2003) and can be detected if there is a continuous air monitoring during a 24 hour period. There are several elements associated with vehicle activities, such as Fe, Br, Cu, Zn, Ba, and Pb (Huang et al., 1994).

1.4.3 Construction

Qatar is considered one of the fastest developing countries with heavy construction activities supported by the strong economy. Since winning the World Cup 2020 bid, construction activities have been sped to build stadiums and infrastructures. A recent study conducted near construction sites in Qatar reported the increased concentrations of PM pollution mainly due to the presence of Calcisols (that resulted from the accumulation of secondary carbonate coming from the construction site) (Hassan et al., 2016). As Qatar characterized by its dry and arid environment (Gopalaswami et al., 2015), erosion of the soil and its suspension in the air column during construction activities will increase the particulate matter pollution.

1.5 Natural Sources

In Qatar, dust storms normally occur within specific months of the year. Qatar is a desert country where no fires could increase the pollutants significantly like forest and tropical forest regions. As a result, the elemental composition of PMs will be consisted of the minerals dust like Ca, Fe, Sr, Si, K, and Ti (Weckwerth, 2001) which are mostly are available in Qatar and outer regional countries.

1.6 Meteorology in Qatar

Qatar is one of the Gulf Cooperation Council (GCC) countries which is characterized by a desert biome. Qatar has characteristic of dry and arid region conditions (Gopalaswami et al., 2015). This leads to hot temperatures in summer and slightly colder temperatures in winter. However, the peninsula shape results in high relative humidity compared to other GCC countries. The most recent data published by the Ministry of Development Planning and Statistics (MDPS, 2013) on the temperature and relative humanity at the Hamad Airport and other stations is presented in (Table 4). According to the report, the maximum average daily temperature in summer reaches 43.3^{o}C and at least 22.5^{o}C in winter. In summer, the average maximum humidity is 66 to 88%, and minimum is 29 to 60%.

Table 4

Maximum and minimum temperatures measured at Hamad Airport during 2012 (MDPS, 2013)

Month (2012)	Extreme Temperature		Number of days with Max. Temp. and Min. Temp. (°C)					
	Absolute Max (ºC)	Absolute Min (ºC)	>=25	>=30	>=35	>=40	>=45	<=10
January	28.0	8.6	5	0	0	0	0	2
February	29.8	11.5	4	0	0	0	0	0
March	37.8	12.8	19	5	2	0	0	0
April	39.8	19.5	30	25	7	0	0	0
May	46.8	27.2	31	31	31	4	1	0
June	47.7	27.6	30	31	30	28	6	0
July	47.6	30.0	31	30	31	31	8	0
August	46.1	29.6	31	31	31	23	2	0
September	43.5	25.5	30	30	30	15	0	0
October	40.5	25.8	31	31	19	2	0	0
November	35.0	18.4	8	17	1	0	0	0
December	31.3	14.3	16	1	0	0	0	0
Annual	47.7	8.6	266	232	182	103	17	2

Table 5

Maximum and minimum relative humidity (%) measured at Hamad Airport during 2012 (MDPS, 2013)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	60	59	49	42	34	29	34	43	43	47	55	62
Max	88	87	82	71	71	66	73	80	77	82	82	88

1.7 Chemical Composition of PM

Particulate matter can differ in physical size and chemical composition (Figure ***2***). Many different chemical compounds have been detected in PM, but they are mainly sulfates, nitrates, elements, polycyclic hydrocarbons, and other organic chemicals. Vega et al. (2001) indicated that the source of PM2.5 is crude oil combustion, followed by road and soil dust. PM10 originates from road, soil, and construction dust.

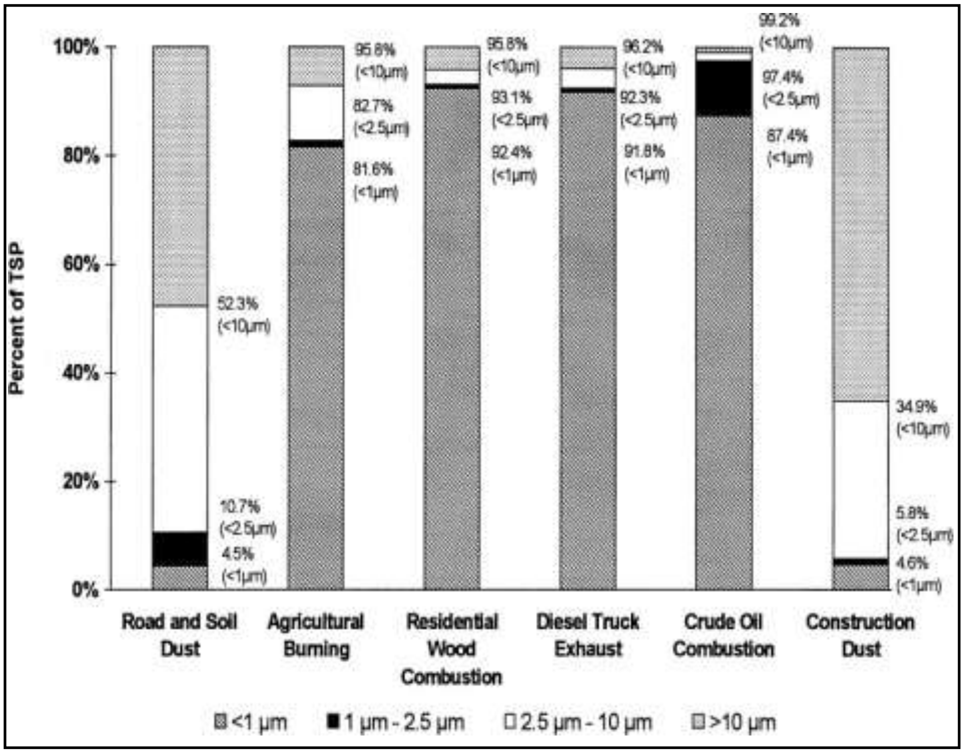

Figure 2. TSP source emission by their size distribution (Vega et al., 2001)

1.7.1 Elemental Composition of PM

The elemental composition of PM depends on spatial and temporal factors. The composition reflects the source and activity around the area. Also, at a certain time of the year, there are higher PM concentrations and it contains a great variety of elements attached to the particles. The elemental composition of PM varies between areas and could depend on industrial, transportation, and meteorological factors. Naimabadi et al. (2016) reported on the PM10 concentration and its composition on normal days and during dust storms. It was concluded that there is no significant connection between their elemental compositions, but the study highlighted that elements in PM10 could lead to cytotoxicity. The study area was similar to Qatar in terms of temperature and near Iraq and Kuwait. The elemental compositions of PM samples determined in this study are shown in Table 6 (Naimabadi et al., 2016).

Table 6

Elemental composition of PM10 samples collected in Iraq and Kuwait (Naimabadi et al., 2016)

Elements	Metal contents of PM10 in dust events day (ng/m^3)		Metals contents of PM_{10} in normal days (ng/m^3)	
	Mean	SD	Mean	SD
Al	35137.76	20751.96	8463.54	5462.89
Fe	28387.17	26348.50	2309.10	1743.20
Zn	34202.83	44192.53	16276	1534.50
Pb	52.06	61.31	25.17	6.14
Cr	72.62	81.36	8.24	9.20
Cu	83.81	40.74	48.18	10.43
Cd	19.50	15.49	18.66	7.98
As	6.67	12.06	4.25	5.03
V	82.96	93.32	6.27	0.30
Ni	74.34	52.77	0.99	1.16

Das et al. (2016) conducted a study in Baranagar, a crowded city in India with high PM emission from anthropogenic sources, between 2013-2014. It was highlighted in this study that the PM concentration surpassed the normal WHO organization limits and reached 783 μg/m^3 (84–783 μg/m^3) for PM2.5 and 928 μg/m^3 (167–928 μg/m^3) for PM10. Many toxic metals were detected in PM2.5, such as Cd, Cu, V, Cr, Ni, Zn, Mo, S, and Sb. Anthropogenic sources, mainly industry, have an enrichment factor for Ni, Cr, and Cu between 100 and 10 ng/m^3, while Sn, Zn, Mo, Sb, Pb, and Cd had an enrichment factors between 1000 and 100 ng/m^3. The elemental composition of PM2.5 in Kavala, Greece was investigated by Loupa et al. (2016). It was found that the highest concentrations of elemental components in PM2.5 were S (1321.0 μg/m^3), followed by Na (657.7 μg/m^3), K (374.68 μg/m^3), Ca (448.00 μg/m^3), Al (360.34 μm/m^3), Si (325.50 μg/m^3), Fe (147.30 μg/m^3), Mg (126.32 μg/m^3), Zn (62.19 μg/m^3), and Ni (4.87 μg/m^3) (Loupa, Zarogianni, Karali, Kosmadakis, & Rapsomanikis, 2016). A recent study focusing on the chemical characteristic of particulate matter monitored indoor and outdoor environments for a duration of two months in Qatar was published by (Saraga et al., 2017). The authors found that there is a positive correlation between indoor and outdoor pollution where pollutants could enter through ventilation system and window/cracks into the building. They concluded that the indoor PM concentrations can be influenced by the outdoor PM concentrations during dusty days. The elemental compositions of outdoor PM 2.5 and PM10 samples collected in Doha as reported in this study is provided in Table 7.

Table 7

Outdoor elemental composition of PM2.5 and PM10 (Saraga et al., 2017)

Concentration (ng m^{-3})		
	PM_{10} outdoors	$PM_{2.5}$ outdoors
Al	4288	2876
Fe	5165	3357
Mn	138	88.8
Ba	115	72.2
Sr	165	111
V	35.7	28.6
Cr	39.3	19.8
Rb	5.41	3.64
Ni	36.6	21.1
Zn	63.8	45.8
Cu	53.7	31.86
Co	3.59	2.24
Ga	1.85	1.22
Pb	20.6	17.77
Cs	0.45	0.31
As	2.03	1.39
Cd	0.27	0.17

1.8 Health Effects of PMs

An association has been established between PM pollution and various kinds of health effects (Cascio, 2016). The WHO reported that three million deaths around the world are a result of air pollution (WHO, 2016). In Europe, PM2.5 pollution was related to 432,000 premature deaths in 2012 due to long-term air pollution exposure (EEA, 2015). PM could affect the cardiovascular system and result in sudden heart attacks (Chan et al.,

2016) and irregular heartbeat. Respiratory effects include asthma (Baldacci et al., 2015) and decreased lung function (USEPA, 2016). There were 428 cases of people who contracted chronic obstructive pulmonary disease in Iran in 2009-2013 (21, 111, 94, 102, and 98 in each respective year) due to air pollution issues (Khaefi et al., 2017).

In recent years, studies have also identified a link between PM exposure and cancer (Raaschou-Nielsen et al., 2016; Loomis et al., 2013; Hamra et al., 2014). PM with different size fractions can cause direct damage to DNA, and changes in DNA could cause cancer when there is no DNA repair mechanism (Lynch et al., 2016). Characterization of the components of PM is important to identify potential risks to human health (Bari et al., 2016). PM2.5 can reach deeper parts of the lungs and cause much more serious health effects compared to PM10 (Khan et al., 2010). A study on more than three million people was carried out to correlate the PM components with cancer in different European countries (Raaschou-Nielsen et al., 2016). It was concluded that the elemental composition is a significant cause of cancer. The study focused on eight elements (Cu, Fe, K, Ni, S, Si, V, and Zn), and highlighted the high levels of S and Ni (Raaschou-Nielsen et al., 2016).

Chen et al. (2016) investigated the mortality and lung cancer with long-term exposure (12 years) to PM. They found that with every increase in PM10 concentration of 10 $\mu g/m^3$, the probability of mortality by lung cancer increases by 3.4–6.0% (Chen et al., 2016). In addition, the concentration of PM is also significant because its individual components can lead to different health effects (Forsberg et al., 2005; Cassee et al., 2013; Peters et al., 2015). Outdoor air pollution, particularly with PM as a major component, is classified as a Group 1 pollutant (carcinogenic to humans) by the International Agency for Research on Cancer (IARC, 2013). Malley et al. (2017) investigated the correlation of

PM2.5 pollution with preterm birth in 183 countries around the world in 2010. The results showed that mothers who are exposed to more PM2.5 pollution have more risk factors that contribute to increasing preterm birth (Malley et al., 2017). In this region, Naimabadi et al.'s study (2016) is the only one which provides a detail information on the link between the composition of PM and negative health effects and cancer. The study did not find a significant correlation ($P > 0.05$) between the composition of PM and its effects on human on normal or dusty days (Naimabadi et al., 2016).

There are several methods and instruments for measuring particulate matter characteristics and concentration. There are two main measurements for PM, which are concentration and size distribution. Concentration measurement of particles has mainly three methods which are Gravimetric (using filters, impactor), optical (Scattering: using Photometer, OPC, and CPC; Extinction: Opacity meter; Absorption: Spotmeter, Aethalometer, PASS, LII) and microbalance. The size distribution measurement has five methods which are the microscopical (using Microscopy), impaction (using Impactor), diffusion (using Diffusion battery), charging (using DMA), and compete systems (using SMPS, CPMA, DMS, FIMS, ELPI, and EDB) (Amaral, de Carvalho, Costa, & Pinheiro, 2015). Most common technique that is used as a reference sampling of PM concentration is the gravimetric method which is also used in this study.

2.1 Justification

Air pollution is known to be a major public health and environmental issue (due to decreased visibility effect) all around the world. The assessment of air quality has been carried out in developed nations, such as the USA, Canada, UK, Germany, etc. and developing nations in Asia, Africa, and the Middle East (e.g. Lebanon, Saudi Arabia, Iraq, Kuwait). A substantial body of epidemiological evidence now exists that establishes a link between exposure to air pollution and increased mortality (especially premature death) and morbidity due to a wide range of adverse cardiovascular and respiratory problems (Lira et al., 2012; Yaacoub et al., 2013; Abdulaziz et al., 2015). The information on the levels of PM and their probable source is very limited in Qatar; hence, there is a need to have a more comprehensive study on the particulate matter in term of its elemental composition and its impact on air quality. Therefore, this study was designed to monitor the levels of PMs (PM2.5 and PM10) at different locations in Qatar by integrating emissions within a framework of geographic information system (GIS) through the use of different mapping techniques depending on the available data. The results obtained from this study will be helpful for decision makers to formulate and implement policies that are feasible and sustainable to protect public health and the environment in Qatar.

2.2 Objectives of the Study

1- Monitor the concentration of particulate matter (PM2.5 and PM10) at different locations in Qatar.

2- Determine the elemental composition of PMs to identify their possible sources.

3- Create a map by using Geographical Information System (GIS) to show the air quality based on PM2.5 and PM10 concentrations at select locations in Qatar.

CHAPTER III: MATERIALS AND METHODS

3.1 Study Site

Five main sampling locations were chosen in this study: Qatar University (QU), (25° 21' 29.8692" N, 51° 29' 34.5984" E), Aspire Zone (25° 16' 2.2332" N, 51° 27' 6.9012" E), Education City (EC) (25° 19' 25.6512" N, 51° 25' 58.3716" E), Wholesale market (WSM) (25° 14' 47.2452" N, 51° 28' 35.1768" E), and Al-Wakrah City (25° 9' 53.1792" N, 51° 35' 38.7456" E) (Figure 3). The main reason for selecting these locations was based on many criteria, such as land use, activities, and traffic density. The selected areas have different forms of land use and have major educational facilities, transportation facilities, industrial buildings, health centers, local schools, and residential buildings.

Qatar University has the largest number of students and faculty members among universities located in Qatar. There are about 14,000 students registered in Qatar University who are not using buses as their main transportation. The majority of students depend on personal transportation to reach the university. In addition to heavy traffic activities, there is a metro being constructed on the northern side of Qatar University, which may affect the concentration of suspended particles in the air.

The Aspire zone is a critical location with common shopping areas, sport facilities, and public parks. At Education city, the activities are similar to those at Qatar University in terms of traffic and construction (metro work) activities, with new building constructions of the Qatar foundation as well. The fourth sampling site is the Wholesale market (WSM), which includes several markets that sell products like fish, animals, vegetables/fruits, and home accessories. Qatar depends mainly on importing food, animals, and accessories, so big trucks and other vehicles of different sizes are common on this market area.

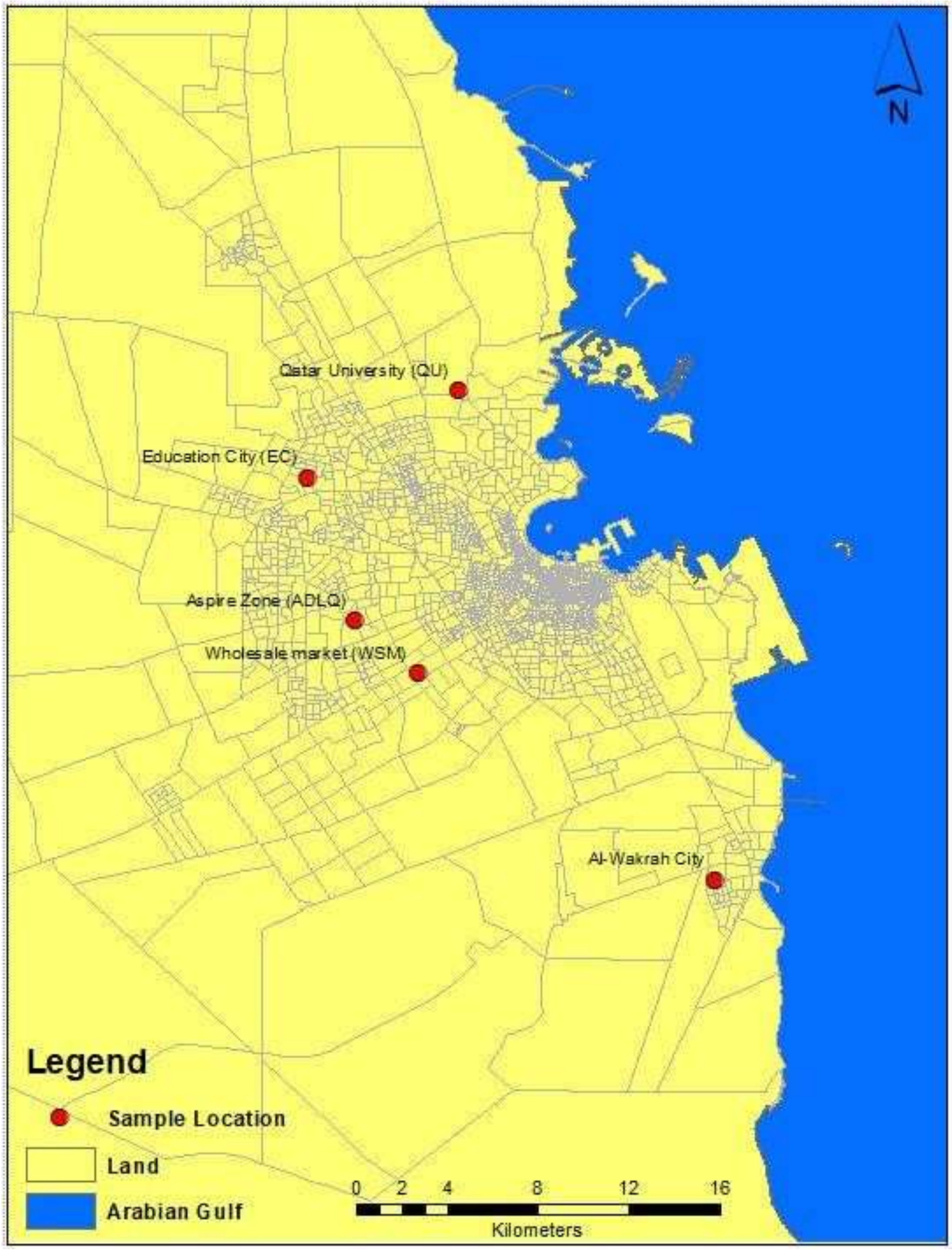

Figure 3. Map of sampling locations.

The fifth location is Al-Wakrah city, which is one of the fastest growing cities in Qatar in terms of residential and industrial activities. It has the oldest and main desalination/electrical plant in Qatar (Ras Abu Fontas, just 2 km away from the center of Al-Wakrah City). With the new marine port (Hamad Port), there is more construction of commercial offices and buildings that started in parallel with metro activities as well. Since being accepted for holding the world cup 2022, there have been increases in terms of population and construction activities in the state of Qatar.

3.2 Sample Collection and on-site measurements of PM2.5 and PM10

Air samples were collected monthly using Deployable Particle Samplers (DPS; Figure 4; SKC Inc., PA, USA) between September 2016 and December 2016. The DPS is a 24-hour Li-Ion battery-operated system that is easy to operate and portable. Five DPS pumps (3 for PM2.5 and 2 for PM10 measurements) were placed at each sampling location. Each DPS was equipped with a compact internal impactor comprising of a PM2.5 or PM10 inlet and outlet, and a 47-mm filter cassette.

Figure 4. Deployable Particle Sampler

The PTFE filters (SKC Omega Specialty Division, PTFE filters 2.0 µm pore size, 47 mm diameter) were weighed by using a microbalance (METTLER TOLEDO XP2U) and conditioned before each sampling time using the method of California Air Resource Base (SOP MLD 055, 2014) with little modification for temperature and humidity based on the available lab condition in Qatar University. The simultaneous sampling on PTFE filters allowed the subsequent chemical determination of all macro-components of PM. The system was maintained at 10.0 L/min flow rate (Table 8) during 24 hours of sampling period once a month with three PM2.5 and two PM10 pumps located at each station.

Table 8

Flow rate measurements of each PM2.5 and PM10 sampling device at the time of calibration

Device	Flow Rate (L/min)	Accuracy
Device#1 PM2.5	9.76	±0.17
Device#2 PM2.5	10.07	±0.04
Device#3 PM2.5	10.13	±0.03
Device#4 PM10	10.09	±0.03
Device#5 PM10	10.14	±0.05

Before each sampling period, each pump was calibrated to confirm the 10.0 L/min flow rate. Height of the sampling sites ranged from 3-15 meters for all five stations where pumps were placed.

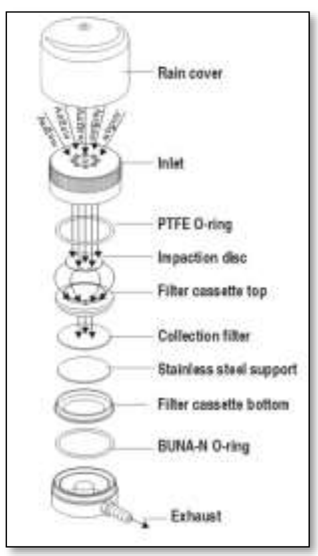

Figure 5. Exploded view of IMPACT Sampler

The formation of ambient PM depends on an interrelated and complex system of emission rates, meteorological processes, and atmospheric chemistry. Thus, data on surface and atmospheric temperatures, dew point, relative humidity, wind speed, wind gust, and sea pressure were obtained from the Qatar Meteorology department. All these data were provided in Appendix A.

3.4 Calculation of PM Mass

The calculation of the concentration of PM was carried out depending on the main equation that is used for PMs in the book of "Code of Federal Regulations Government: 1985-1999" (United States. Office of the Federal, 1994). The average sampling flow of each device was recorded initially and after 24 hrs. Total dust collected on filters were divided by the air volume of 24 hrs of sampling to have the PM2.5 and PM10 levels. The initial and final weight of samples recorded to get collected dust weight. The following formula (Actual PM concentration at field condition) was used to calculate the PM2.5 and PM10 concentrations (Appendix B).

$$C = PM_{act} (P_{std} / P_{act}) (T_{act} / T_{std})^*$$

(United States. Office of the Federal, 1994)

C= Actual concentration of PM at field conditions (µg/m^3)

PM_{std} = Concentration at standard conditions (µg/m^3)

P_{act} = Average barometric pressure at the field during sampling (mm Hg)

P_{std} = 760 mm Hg

T_{act} = Average ambient temperature at the field conditions during the sampling period (K)

T_{std} = 298 K

* Detailed formula sequences is available in Appendix B.

3.5 Identification of the elemental composition of PMs

The elemental compositions of all PM samples were determined using the USEPA method 200.7 Revision 4.4 (EPA, 1994). The following elements were targeted based on their known presence in PM samples: Al, Ca, Na, Mg, Fe, K, Cl, Li, P, Ti, V, Cr, Mn, Co, Ni, Zn, As, Se, Rb, Sr, Cd, Sn, Sb, Ba, Pb, and Hg. Calcium, Si, Fe, Al, K, and Ti are crustal elements; Mg, K, and Na come from sea salt; and heavy metals such as Cd, Hg, Pb, etc. are from traffic or industrial pollution. The PTFE filters were collected from different stations and weighed within available lab conditions following the California Air Resource Base (SOP MLD 055, 2014) with some modification for temperature and humidity (using available material at the university). After 24 hrs sampling, the filters were removed from the impactor, placed in a sterile plastic dishes and brought to the acid digestion lab in the Environmental Science Center at Qatar University. Filters were put in PTFE tubes, and HNO_3 70-68% (12 ml) and HF 40% (3 ml) were added at different times. Digested samples were transferred to new tubes for analyses by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) Model Optima 7300 DV (Perkin Elmer Inc., Waltham, MA, USA) located in the Central Lab Unit (CLU) at Qatar University. The instrumental characteristics and operating parameters of ICP-OES are summarized in Table 7. A Blank, Duplicate, and CRM (certified Reference Material) were included as quality control. The accuracy of heavy metal measurements was evaluated using the Multi Element standard solution IV (Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Tl, Zn Fluka Analytical, Busch, Switzerland). Selection of the elements was based on the main heavy metals and other elements in the air as determined previously (Khan et al., 2010; Segalin et al., 2017). The standards were dissolved in 1% HNO_3 and four major concentrations were prepared to establish a calibration curve of the target elements.

Table 9
Tuning parameters of the ICP-OES

Instrument	Optima 7300 DV
Nebulizer/Spray chamber	Meinhard/Cyclonic
Injector	Quartz 2.0 mm ID
Resolution	Normal
Read Time	20 sec (min) – 50 sec (max)
Resolution	Normal
Plasma Gas	15 L/min
Auxiliary Gas	0.2 L/min
Nebulizer Gas	0.6 L/min
Power	1400 W
Plasma View	Axial

3.6 Determination of PM sources using Enrichment factor (EF)

The enrichment factor was used to highlight the possible source of particulate matter elemental composition. It is based on using a reference crustal element as natural source and comparing it with particulate matter composition. Al and Fe can be used as reference elements as previously reported (Chan et al., 1997).

The EF values were calculated using Al as a reference element that gotten from Rudnick and Gao (Rudnick & Gao, 2003) , and applied on the following equation:

$$EF=[(Xa/Refa)_{Sample}/(Xc/Refc)_{Crustal}] \qquad \text{(Chan et al., 1997).}$$

Where:

Xa=Target element in air PM samples.

Refa=Reference element in air PM samples (ex. Al).

Xc=Reference element from crust like target element.

Refc=Reference element from crust (ex. Al).

3.7 Determination of Air Quality

The air quality based on PM2.5 and PM10 concentrations was determined using the Air Quality Index (AQI) tool. This tool categorizes the health risk based on the following specifications: Good air quality (Index value 0-50), “Moderate” air quality (51-100), “Unhealthy for Sensitive Individuals” (101-150), “Unhealthy’ (151-200), “Very Unhealthy” (201-300), and “Hazardous” air quality (301-500) (Table 10). Calculation of the AQI can be done by the official web site of AQI calculator (www.AirNow.gov) to convert the PM concentration to one of the AQI category. By using AQI, people can take a decision that is related to their living/working locations, and reduction of air pollution.

Table 10

Air Quality Index categories by Level of Health concern and Colors (AirNow, 2016)

Air Quality Index (AQI) values	Level of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

3.8 Mapping of AQI values calculated based on PM concentrations and Land use

ArcMap 9.3 software was used to compute Air Quality Index (AQI) values calculated based on the daily concentrations of PM2.5 and PM10 at each sampling location. The AQI tool is available on the USEPA's website which is used to categorize the health risks associated with different levels of PM2.5 and PM10. Furthermore, land use maps were also included in this study to highlight the main land use activity surrounding sampling stations.

3.9 Statistical Analysis

Different statistical correlation models were used to determine the significant relations between PMs, elemental composition, and meteorological data. The Statistical Analysis System (SAS Institute Inc., Cary, NC, USA) software was used to apply generalized linear model (GLM) using ANOVA to determine the significant differences between PM concentrations and their elemental compositions at different sampling locations and months at $p<0.05$.

CHAPTER IV: RESULTS AND DISCUSSION

4.1 PM Concentrations by Location and Month

A total of 100 samples (60 of PM2.5 and 40 PM10) were collected for four months starting from September to December 2016. The overall mean concentrations of PM2.5 and PM10 ranged from 50 μg/m^3 to 64 μg/m^3 and 127 μg/m^3 to 185 μg/m^3, respectively (Table 11).

Table 11

The mean concentrations of PM2.5 and PM10 samples collected from different Stations and Meteorological data

	Stations				
Parameters	Qatar University	Education City	Aspire Zone	Whole Sale Market	Al Wakrah
Average PM2.5 Conc. (μg/m^3)	**50±2.47**	**65±1.90**	**55±2.24**	**59±3.01**	**57±2.68**
Average PM10 Conc. (μg/m^3)	138±3.72	**156±3.06**	127±3.90	**185±3.64**	**160±2.79**
Temperature (°C)	26.90±1.16	27.92±1.18	26.97±1.15	28.00±1.26	26.47±1.25
Wind Speed (m/s)	1.75±0.32	1.80±0.26	1.80±0.35	2.10±0.52	4.15±0.60
Humidity (%)	60.00±1.78	59.25±1.97	61.00±2.02	50.00±1.01	62.00±1.24

The concentrations of both PM2.5 and PM10 were relatively higher than the EPA standards (for PM10= 150 µg/m^3 and PM2.5 = 35 µg/m^3) and WHO Standards (PM10= 50 µg/m^3 24 hr mean and PM2.5 = 25 µg/m^3 for 24 hrs), as well as Qatari Ministry of Environment and Municipality (only 150 µg/m^3 for PM10) standards (Figure 6, Tables 1 and 3).

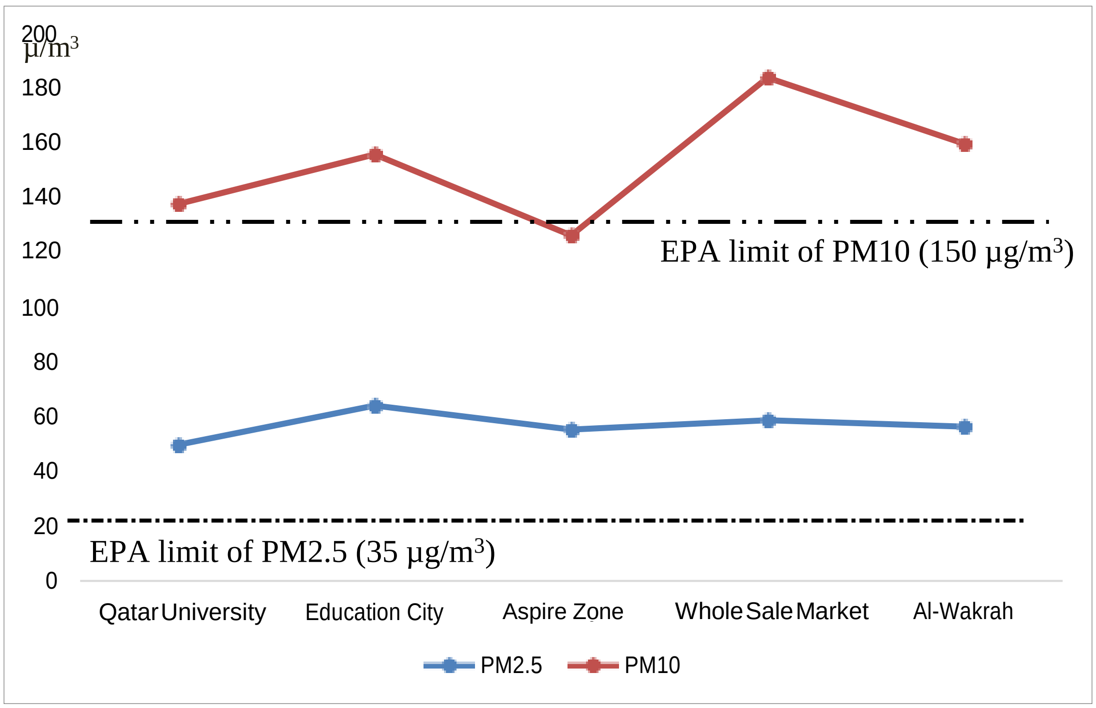

Figure 6. The comparison of the USEPA standards and the average mean concentrations of PM2.5 and PM10 recorded at different locations during the study period.

These results were expected since Qatar is an arid region known for its frequent dust storms and dusty environment. In a recent study, Saraga et al. (2017) reported the indoor and outdoor PM2.5 and PM10 levels being higher than 25 and 50 µg/m^3 (WHO standards) on most of the sampling days between April 22, 2015 and June 21, 2015 in Qatar. Similar findings were also recorded in Kuwait, indicating poor air quality based on PM2.5 levels (Brown et al., 2008).

A high concentration of PM10 was recorded at three stations: Wholesale Market, Al Wakrah City, and Education City, with concentrations of 185 µg/m^3, 160 µg/m^3, and 156 µg/m^3, respectively (Table 11). The concentration of PM2.5 reported at all five stations exceeded the EPA daily limit of 35 µg/m^3 (Figure 6), indicating relatively poor air quality around these areas. The PM2.5 concentrations at Qatar University, Education City, WSM, Al-Wakrah City, and Aspire Zone were 50, 64, 59, 57, and 55 µg/m^3, respectively (Table 11). These high levels could be due to different human activities as observed in these stations.

The Wholesale Market (WSM) is an economic activity site where fish market, animal market, and produce market receive most of Qatar's food imports. Massive movement of trucks to transport food supplies to the market on unpaved road creates suspended particulate matter. There is an open area on the southern side of WSM and a semi-closed road that uptakes dust particles that come from the open area near the animal market when the wind is blowing from south of WSM which is the area with heavy traffic and logistic activities/industries (Figure 10). This could be one of the contributing factors for PM10 levels reaching considerably high concentrations compared to other sampling sites. Such findings were also supported by Zhu et al. (2015) and Patra et al. (2008) who mentioned that the concentration of PM10 close to roads is due to resuspended particles. Another factor which might result in high PM10 levels recorded at WSM is large cattle feedlots that supply the local market with cattle meat, which is under category of low to medium impact industries, and there is large logistic area for governmental ministries (Figure 10). The relationship between the cattle areas and high PM10 concentration was previously reported by (Guo et al., 2011).

In April 2017, the fish market and animal market at WSM was partially moved to UmSalal area located in the north of Qatar. As a result of this change, a reduction in PM10 levels is expected, but this hypothesis needs to be tested since this study only covered the period of September to December 2016.

The highest mean concentrations of PM2.5 and PM10 were monitored at concentrations of 64 $\mu g/m^3$ and 185 $\mu g/m^3$ at Education City and WSM, respectively (Table 10). Education city is recognized as one of the fastest growing sites in Qatar. The sampling station at EC was in the middle of Education City, which is surrounded by several universities and facilities that are still under construction -which considered as a temporary state-. During sampling, construction work was ongoing near the sampling station at EC, which may have contributed to high concentrations of both PM2.5 and PM10 as recorded at this location. The area is also housing many educational institutions, the largest convention center in Qatar, and many commercial sites. The vehicle movement in this area could also be another important factor contributing to the high concentrations of PMs (Araújo, Costa, & de Moraes, 2014).

4.2 Air Quality Index Values Calculated based on PM2.5 and PM10 Concentrations

Air quality index (AQI) tool is recognized as one of indexes to determine health risks associated with PM levels based on the USEPA guidelines. It categorizes the air quality based on 24 hr PM concentrations using color codes, such as green for Good, yellow for Moderate, orange for Unhealthy for sensitive groups, red for Unhealthy, purple for Very unhealthy, and maroon for Hazardous air quality levels (AirNow, 2016). Air quality is progressively known as a serious issue for human health and is a subject for which comprehensive global emission data are missing. Using AQI, the quality of local air can be determined and a warning system can be created to inform the public, especially sensitive groups to protect their health.

The AQI values calculated based on PM2.5 concentration indicated that the air quality was in “moderate” range in September and December. While, the AQI levels exhibited “Unhealthy” rating during the months of October and November (Table 12). The 24 hrs mean levels of PM10 resulted in relatively better AQI levels which were reported mainly in the “Moderate” category during the entire sampling period, compared to the means of PM2.5 (Table 12) . These differences in AQI during sampling days are important to highlight human activities which were relatively low in September and December due to national holidays and late start of schools in September and winter breaks in December. On the other hand, human activities are at the highest levels in the months of October and November since schools/universities are open and running in full-term. Based on the AQI levels calculated using the concentrations of PM2.5 and PM10, there were 25%, 37.5%, and 37.5% of total days in the category of “Unhealthy”, “Moderate”, and “Unhealthy air quality for Sensitive Groups” during the study period, respectively (Figure 7). It is noteworthy to mention that there was no single day with "good" air quality during the four months of sampling, demonstrating that air quality associated with PM air pollution could be a significant public health issue in Qatar. Even the PM levels are considered high in Qatar based on the findings obtained in this study and the recent report published by WHO (2016), the number of death and respiratory illness related to PM pollution is surprisingly low. This might create an opportunity for the public agencies to review current standards and establish more reasonable standards considering the arid environment of Qatar since most PM pollution is be realted to natural sources.

Table 12

The Air Quality Index Values calculated based on the concentrations* of PM2.5 and PM10 during the study period

	Air Quality Index Values	
Month	PM2.5	PM10
September	104 Unhealthy for sensitive group (37 µg/m3)	93 Moderate (140 µg/m3)
October	156 Unhealthy (66 µg/m3)	100 Moderate (154 µg/m3)
November	73.01 Unhealthy (66 µg/m3)	111 Unhealthy for sensitive group (176 µg/m3)
December	142 Unhealthy for sensitive group (52 µg/m3)	95 Moderate (144 µg/m3)

*Values in parentheses are PM2.5 and PM10 concentrations.

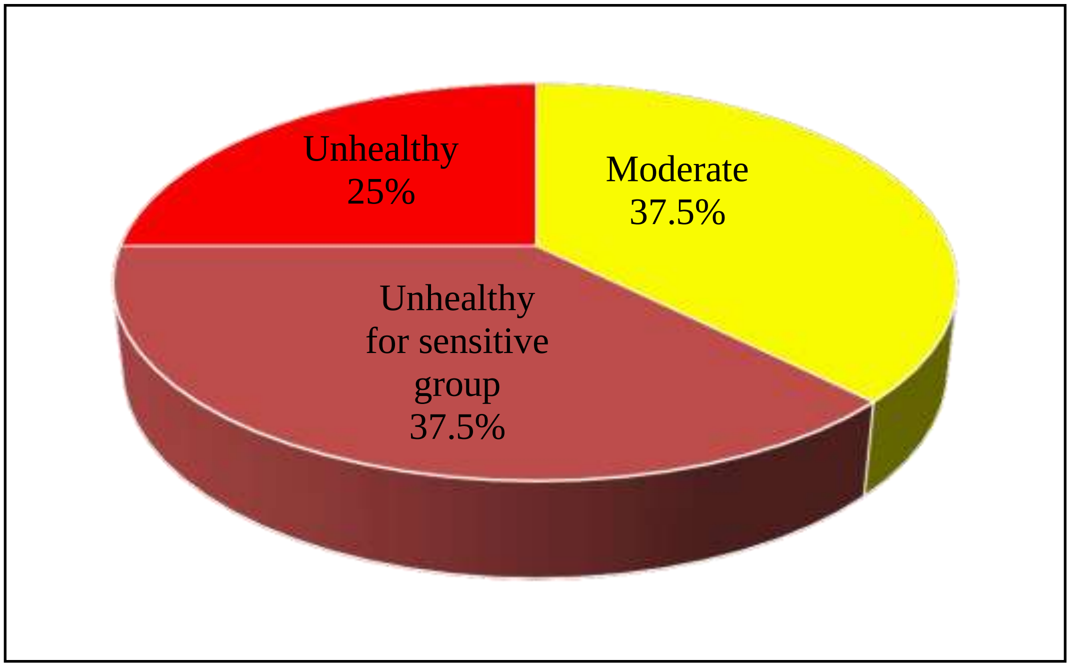

Figure 7. The percentage distribution of different Air Quality Index ratings during the sampling months.

At Qatar University and Aspire Zone areas, the AQI levels indicated "Moderate" air quality for PM10 levels and "Unhealthy air quality for sensitive groups" for PM2.5 levels (Table 12). These two locations share similar land use exercises and have many green areas with dense tree population compared to other study sites (Figures 8 and 9). McDonald et al. (2007) investigated the positive changes in particulate matter of urban tree planting on the concentrations and depositions of particulate matter, and found that PM10 levels can be reduced up to 26% if tree density is increased. Trees also can support the air quality by removing 4.7 ton of PM2.5 annually (Nowak et al., 2013). Three of five stations included in this study had “Unhealthy” air quality rating, which might negatively impact human health (Table 13). However, this correlation needs to be further investigated to establish the link between unhealthy air quality associated with high concentrations of PMs and their health effects on human, especially on sensitive groups by using data on health statistics.

Table 13

Air Quality Index Values calculated based on the four month averages of PM2.5 and PM10 at different stations

	Air Quality Index	
Location	PM2.5*	PM10*
Qatar University	136 Unhealthy for sensitive Groups (50 µg/m3)	92 Moderate (138 µg/m3)
Education City	155 Unhealthy (64µg/m3)	101 Unhealthy for sensitive Group (156 µg/m3)
ADLQ (Aspire Zone)	150 Unhealthy for sensitive Group (55 µg/m3)	86 Moderate (126.69 µg/m3)
Whole Sale Market	153 Unhealthy (59 µg/m3)	115 Unhealthy for sensitive Group (185 µg/m3)
Al Wakrah	152 Unhealthy (57 µg/m3)	103 Unhealthy for sensitive Group (160 µg/m3)

*Values in parentheses are the average concentrations of PM2.5 and PM10 collected for a period of four months.

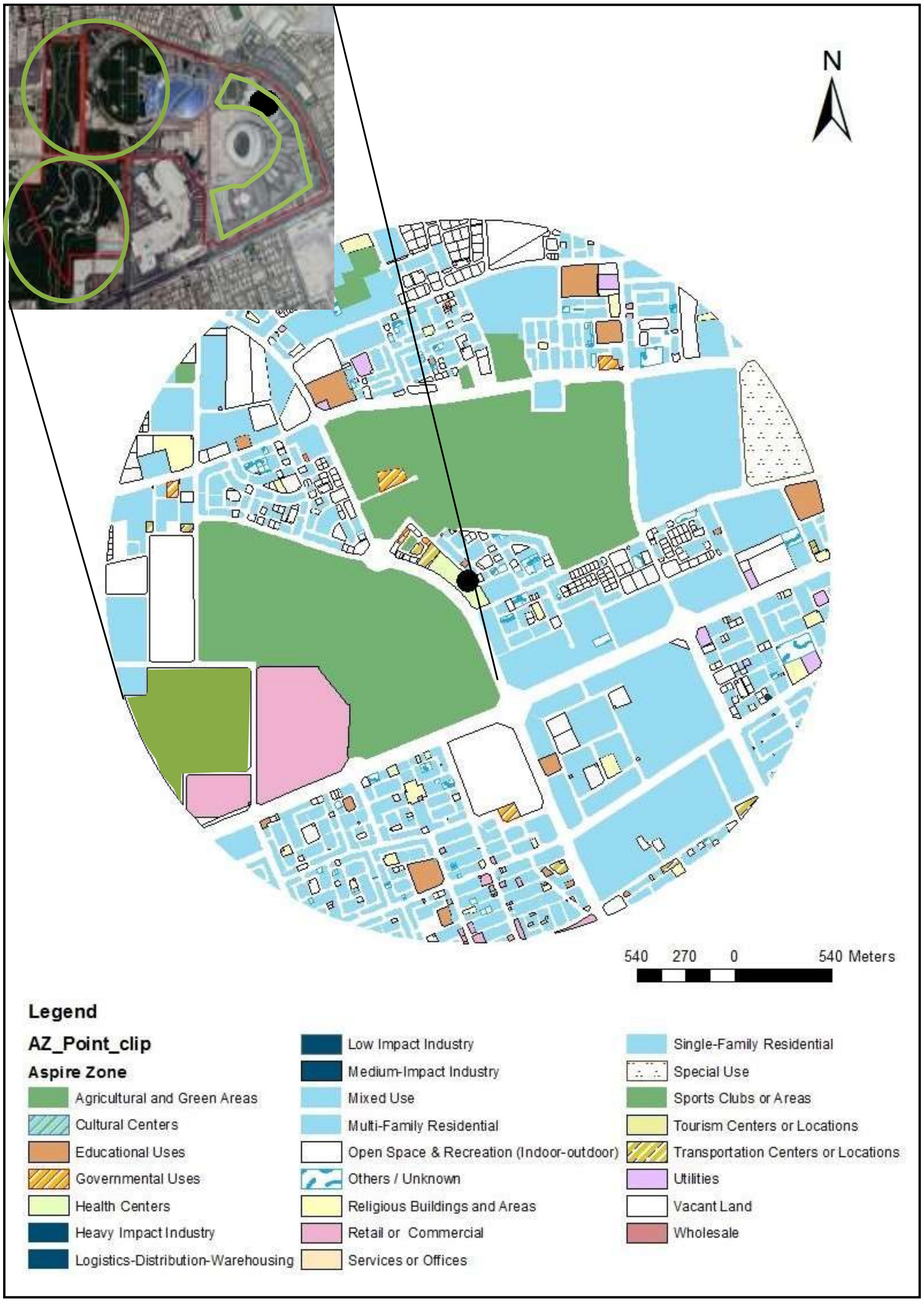

Figure 8. Land use Illustration at Aspire Zone

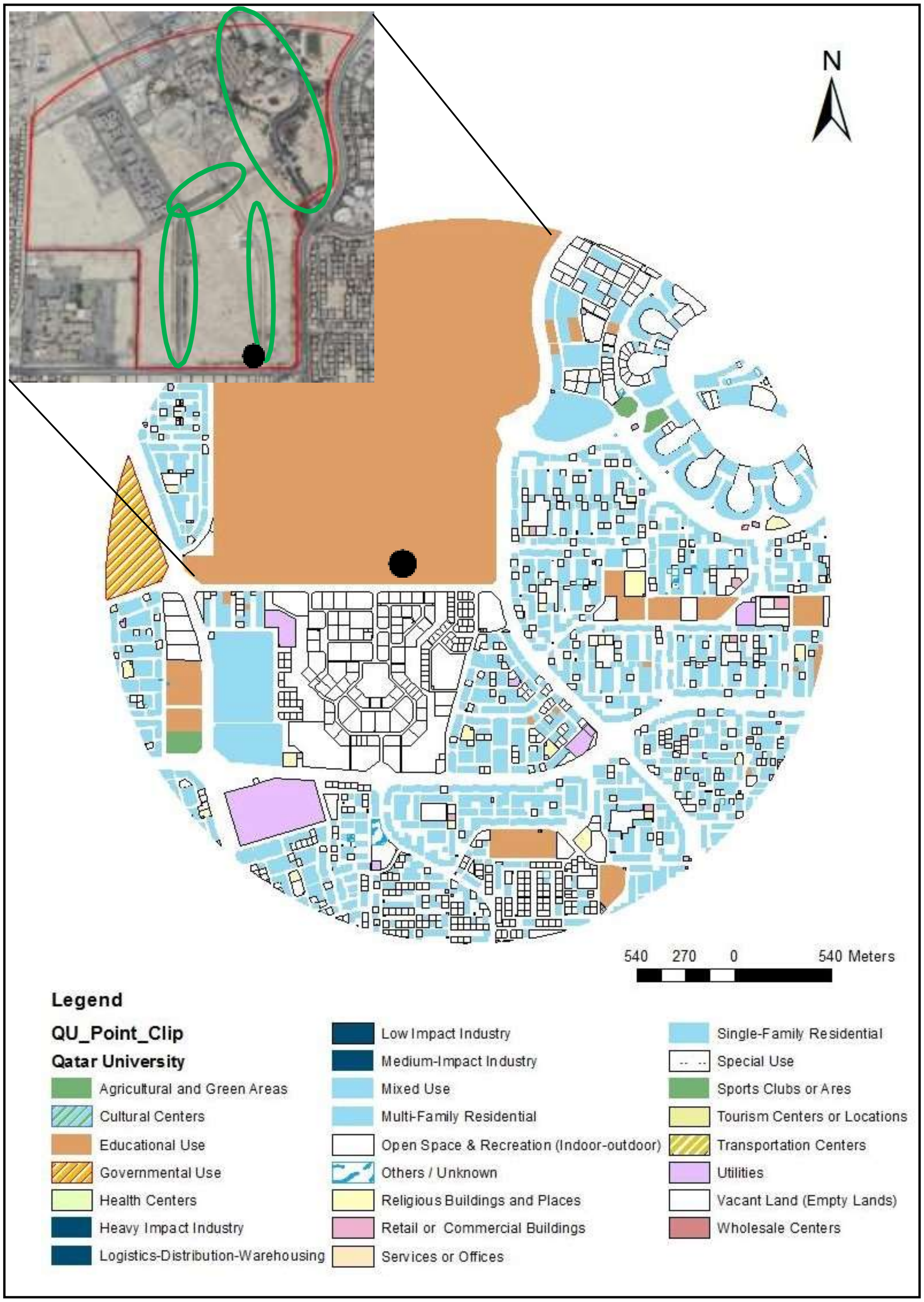

Figure 9. Land Use Illustration at Qatar University

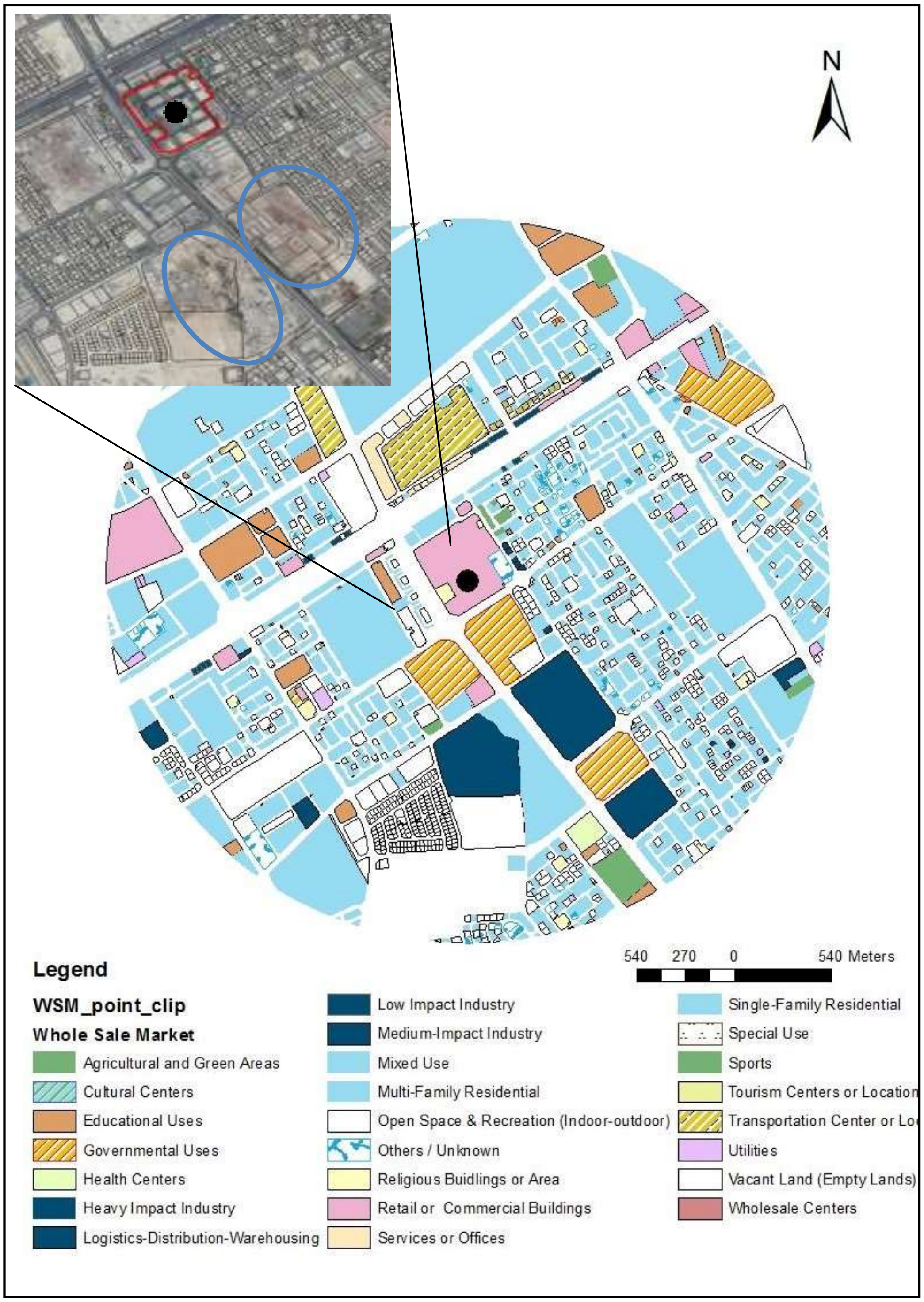

Figure 10. Land Use Illustration at Whole Sale Market

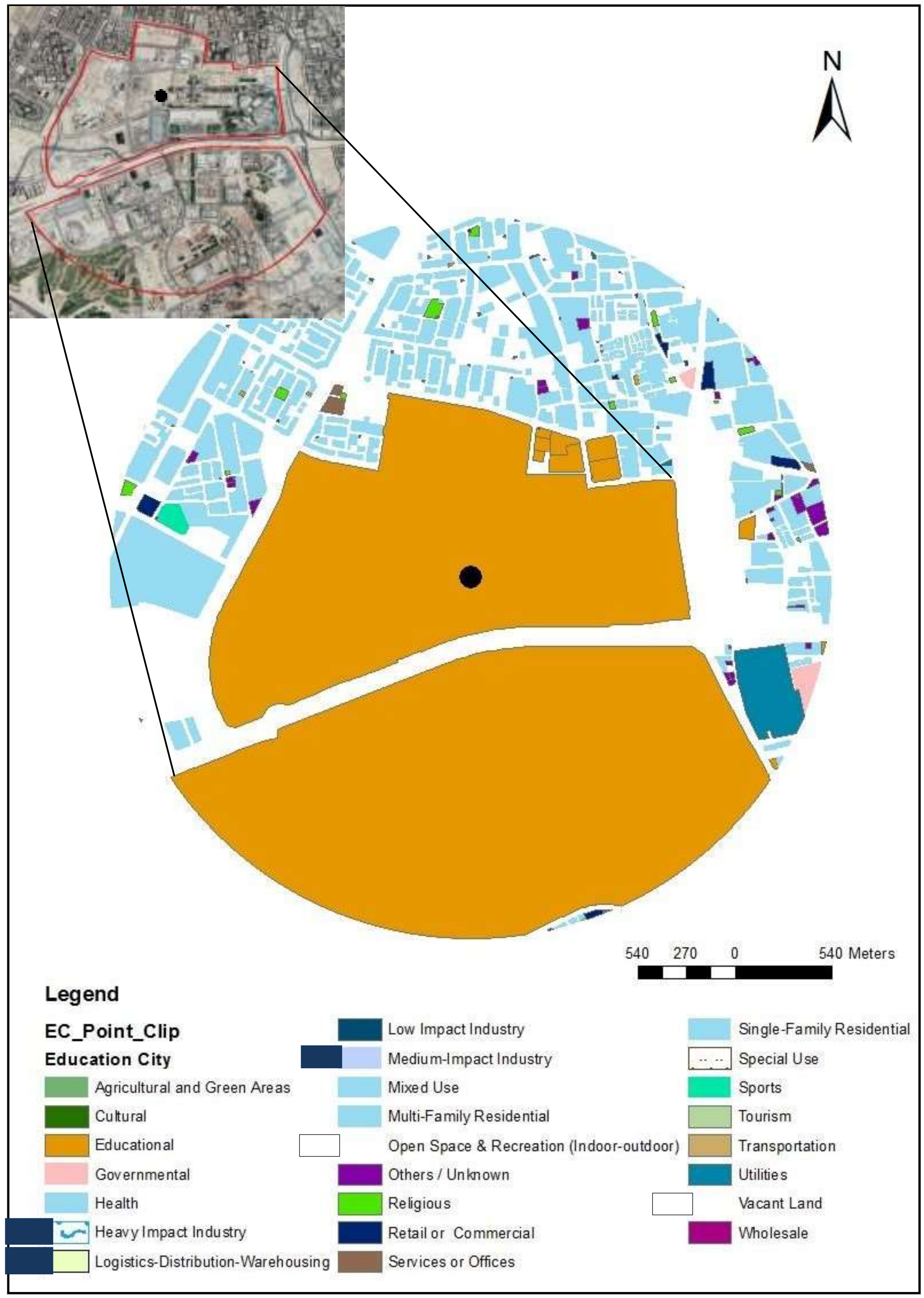

Figure 11. Land Use Illustration at Education City

4.2 Mapping of AQI Values Based on PM2.5 and PM10 Concentrations

The AQI values calculated based on PM concentrations at five stations during the moths of September-December 2016 were computed using GIS in combination with Google Earth mapping system. Figures 12 and 13 illustrate the AQI category for each site. Orange color was the dominant color in both maps, meaning that the air quality was considered “Unhealthy for sensitive groups” at these locations. This is a concern for part of the society who live in these areas since they can be directly affected by poor air quality. People with respiratory diseases, children and elderly are the groups who are at risk to be affected the most as a result of poor air quality as determined in this study. Such conditions might exacerbate likelihood of respiratory symptoms and aggravation of lung diseases, such as asthma. People who have heart and lung diseases could also be affected by poor air quality -specifically particulate matter pollution- as reported in previous studies (Gauderman et al., 2007; Pope et al., 2006; Zanobetti et al., 2000). Martins et al. (2004) reported that the mortality of elderly people increased from 1.4% to 14.2% in Brazil when the concentration of PM10 increased by 10 $\mu g/m^3$.

AQI values indicating “unhealthy” air quality (red color) based on the 24 hr mean PM2.5 concentrations were detected for three stations which were Education city, Whole Sale Market, and Al Wakrah city (Figure 12). This condition could lead to adverse health effects even in healthy people and could cause serious health consequences for sensitive groups. A similar pattern was also observed for PM10-based AQI levels at the same sampling station (Figure 13), meaning that there is a positive correlation between high concentrations of PM2.5 and PM10 and dangerous AQI categories (Mohan & Kandya, 2007).

Figure 12. PM2.5 based Air Quality Index Values at the sampling stations

Figure 13. PM10 based Air Quality Index Values at the sampling stations

4.3 Particulate Matter Elemental Composition

The total concentrations of elements detected in PM2.5 and PM10 samples collected from five stations on different days are listed in Tables 16 and 17. The concentrations of elements in PM samples were comparable to previous studies from the Middle East region (Brown et al., 2008; Saraga et al., 2017).

It is important to note that there was a significant correlation between elemental composition of PM2.5 and PM10 and sampling location. The concentration of elements detected in PM10 samples was significantly different ($p<0.001$) at each sampling location. The highest significant differences were observed among crustal and non-crustal elements, such as Al, Ca, Mg, Fe, Li, V, Cr, Mn, Ni, Co, , As, Sr, , Ba, Pb, while the concentration of Na, Zn , and Cd were not significantly different ($p>0.05$) at different sampling locations. There was also monthly variations in terms of elemental composition of PM10 samples, especially for (Al, Na, Mg, Fe, Li, V, Ba, and Pb) with ($p<0.001$) (Appendix C). (Cheung et al., 2011) also determined a significant correlation between the elemental composition of PM samples and sampling time of the year.

The highest concentrations of elements were detected in PM10 samples collected from WSM. Al, Ca, Na, Mg, Fe, Cr, Ni, Co, Sr, Cd, and Ba had significantly ($p<0.05$) higher levels compared to other stations (Table 17), while the concentrations of the same elements (Al, Ca, Mg, Fe, V, Ni, and Cd) were recorded at the highest level for PM2.5 samples collected from Education City (Table 16).

It is expected that industrial and economic sites like the Wholesale market would normally have higher concentrations of metals such as Cr, Ni, and Ba as the land use illustration indicates (Table 16). It is important to compare the results obtained in this study with others from the same region to be sure that there is no increase of toxic elements in the air column. The highest concentrations of toxic non-crustal elements such as Cr, Ni, V, Pb, and Cd were 26.66, 21.87, 22.78, and 0.65, 4.91 ng/m^3 for PM10 and 17.48, 12.06, 14.77, 2.57, and 0.69 ng/m^3 for PM2.5, respectively (Tables 16 and 17).

A previous study conducted in Qatar by Saraga et al. (2017) recorded some of these elements: Cr (39.3 ng/m^3), V (35.7 ng/m^3), Cd (0.27 ng/m^3), and Pb (20.6 ng/m^3) in PM2.5 samples collected from a site known to have busy traffic. In another study, Naimabadi et al., 2016 reported the presence of similar elements in PM samples collected from a desert in Iran (another Middle East country), which has a similar climate to the Arabian region. The authors recorded high elemental concentrations of heavy metals during the dusty period, which is the most dominant time throughout the year in Qatar. The concentrations of Cr (72.62 ng/m^3), Ni (74.34 ng/m^3), V (82.96 ng/m^3), and Pb (52.06 ng/m^3) were three times higher than the values determined in this study (Naimabadi et al., 2016).

Investigation of the relation of the elements was based on grouping them according to their possible source. Determination of Ca, K, Al, and Fe in PM samples usually indicates the source as upper earth crust. Other elements like Cu, Zn, and Pb are mainly considered as indicators of traffic emission elements (Querol et al., 2001; Manoli et al., 2002; Fang et al., 2003). Elements such Ni and V are recognized as elements coming from burning fossil fuel, and other trace elements such as Cr and Cd result from burning coal. Ni, Cr, Cu, Sn, Zn, Mo, Sb, Pb, and Cd indicate the source as industrially related pollution (Das et al., 2015).

The concentrations of crustal elements such as Al and Fe were relatively high in all samples collected in this study, which is expected since these elements are the normal properties of desert dust. In all stations, the concentrations of non-crustal elements were lower compared to a previously reported study in Qatar (Saraga et al., 2017). This could be due to sampling location and duration. The locations chosen in this study had different activities and sampling was carried out during a warm season. While, Saraga et al. (2017) conducted PM sample collection during the hot season (July) in an area known to be highly crowded part of Doha.

Table 14

Elemental composition concentration of PM2.5 samples collected from different locations

	PM2.5 Mean Elemental Composition Concentration (ng/m^3)				
	QU	**EC**	**AZ**	**WSM**	**AW**
Al	352.19± 28	628.47±66	452.04±118	555.10±105	314.66±58
Ca	5176.29±529	6808.56±884	4820.03±942	5332.94±647	4168.10±451
Na	620.374±303	443.47±148	647.43±382	397.89±71	319.55±56
Mg	485.43±89	738.49±68	601.47±175	640.94±75	407.84±46
Fe	450.20±36	666.18±65	532.95±111	630.68±105	354.46±49
Li	0.10±0	0.24±0	0.32±0	0.24±0	0.64±0
V	11.9892±1	14.7705±1	9.42±1	11.91±1	11.02±0
Cr	14.72±0	15.2453±0	15.95±1	17.48±0	13.26±1
Mn	6.27±0	10.04±1	11.18±1	10.59±2	7.13±0
Ni	11.76±1	12.06±0	11.66±1	11.75±0	10.68±0
Zn	201.79±15	218.76±22	188.53±17	198.65±19	223.98±0
Sr	10.53±2	14.01±2	9.15±2	13.41±1	6.88±0
Cd	0.55±0	0.69±0	0.51±0	0.59±0	0.60±0
Ba	16.32±1	15.68±1	11.45±1	20.58±1	11.12±1
Pb	**2.57**±1	ND*	1.74±0	1.86±0	1.56±0

* ND. Not detected elements.

Table 15

Elemental composition concentration of PM10 samples collected from different locations

	PM10 Mean Elemental Composition Concentration (ng/m^3)				
	QU	**EC**	**AZ**	**WSM**	**AW**
Al	1275.32 ±191	2701.46 ±410	2215.90 ±443	2980.44 ±685	2106.97 ±389
Ca	10238.49 ±2705	19238.23 ±2909	17681.85 ±3479	21286.56 ±2766	20222.25 ±3078
Na	1036.78 ±176	1241.33 ±162	1165.43 ±234	1260.99 ±166	1223.14 ±166
Mg	1992.07 ±550	3814.10 ±507	3462.83 ±697	4507.67 ±650	3768.90 ±335
Fe	1645.29 ±246	2832.27 ±414	2425.55 ±385	3359.17 ±657	2258.90 ±302
Li	0.68±0	2.02±0	1.59±0	2.20±0	2.42±0
V	16.70±2	22.78±1	17.66±1	22.23±2	19.02±1
Cr	18.98±0	22.28±1	22.66±1	26.66±1	21.97±1
Mn	19.88±3	30.14±4	31.73±5	33.01±4	27.94±3
Ni	17.36±1	20.33±0	18.17±1	21.87±1	16.97±1
Zn	157.71±20	233.43±39	263.03±37	183.33±23	318.35±58
Sr	36.41±9	61.31±9	47.13±8	74.88±11	49.41±4
Cd	0.64±0	0.54±0	0.42±0	0.65±0	0.44±0
Ba	51.17±11	54.84±5	47.92±5	80.57±10	53.34±5
Pb	2.99±1	0.37±0	2.76±1	3.16±1	4.91±1

PM samples collected from Qatar University had much lower elemental concentrations compared to Education city. For PM10, just two peak values recorded for toxic non-crustal elements (Cr and Ba), while the concentrations of other toxic non crustal elements like Ni, Cd, and Pb were not significant comparing to other stations (Table 16). For PM2.5, there was a peak recorded for Pb, which is directly related to traffic pollution. Diesel fuel from trucks is the main source of Pb since most cars use lead- free gasoline in Qatar. The sampling location at Qatar University was right next to the main road (Figure 14), while at Education city, the station was not very close to the street (Figure 15).

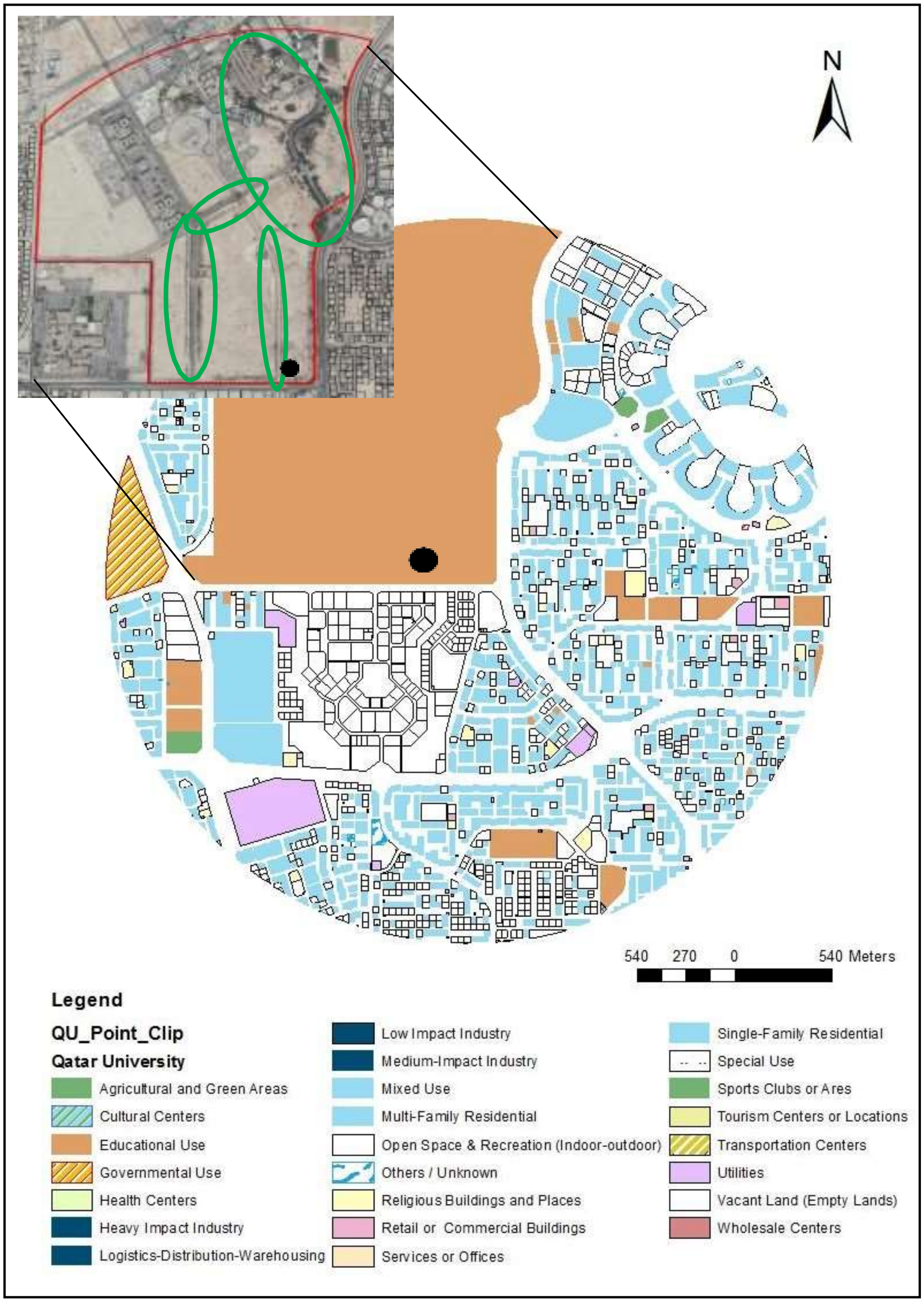

Figure 14. Illustration of Land use at of Qatar University

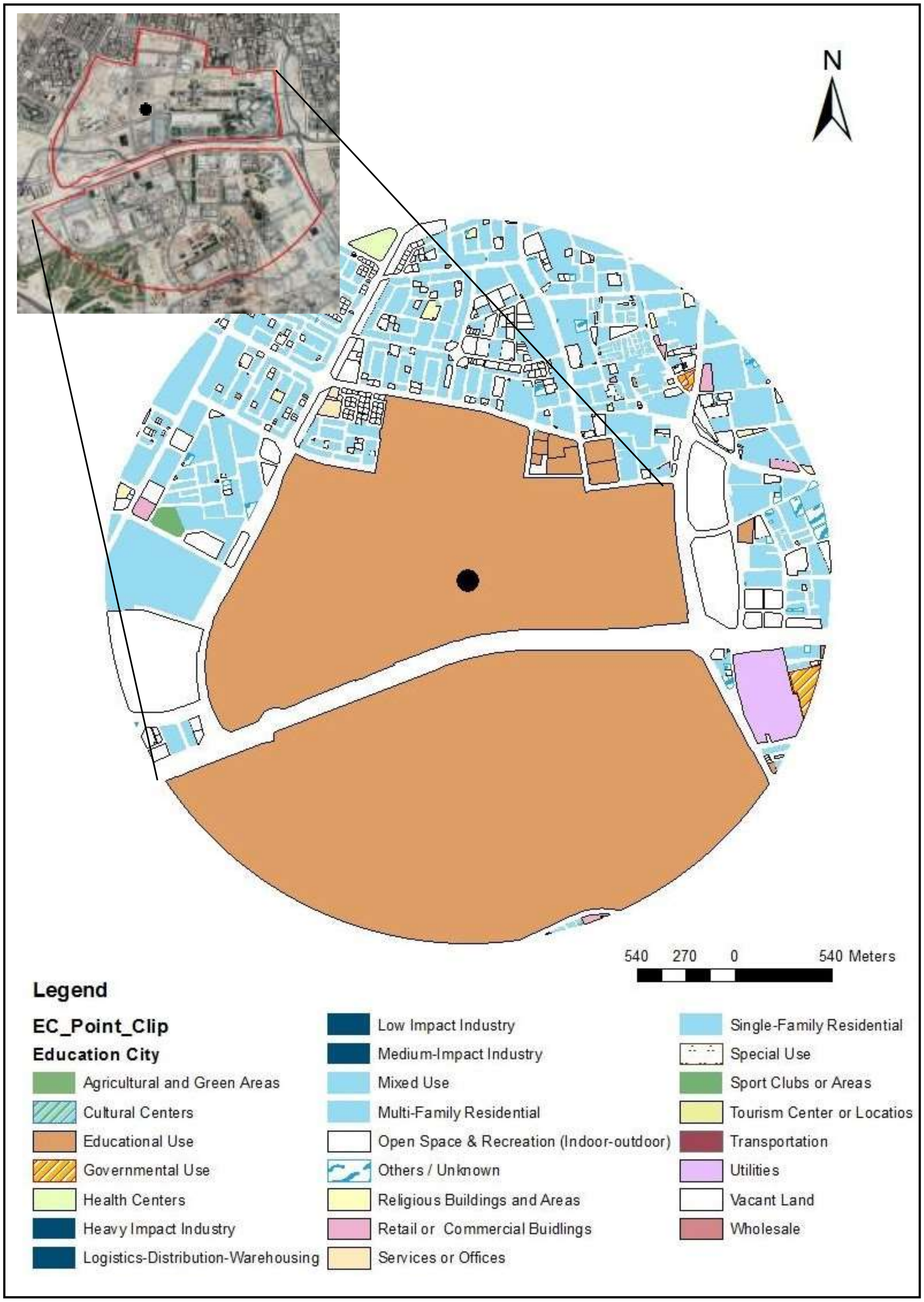

Figure 15. Illustration of Land use at Education City

The spatial distribution of the elements varied by location based on the land use activities as illustrated in the study areas. Compared to other studies (Saraga et al., 2017; Hassan et al., 2016), the concentrations of heavy metals in PM2.5 and PM10 samples collected from different locations in Qatar were relatively low. These concentrations can give a general picture of the air quality level in the areas monitored in this study. Figures 16 and 17 show the concentrations of main elements related to the anthropogenic sources (Cr, Pb, Cr, Li, Cd, and V). Cr had the highest level in both PM samples collected from WSM station compared to other stations, exceeding 26 ng/m$^{3.}$and 17 ng/m^3 for PM10 and PM2.5, respectively. The highest concentration of chromium highlights the source as industrial origin.

Pb is recognized as one of the main indication of traffic related PM pollution due burning diesel in vehicle engines (Wang et al., 2003). The concertation of Pb recorded at the highest concentration in QU for PM2.5 and in Al-Wakrah for PM10. The lowest concentration of Pb recorded in EC. Since the sampling location at EC was not very near a roadside, PM pollution source is probably mainly due to construction activities.

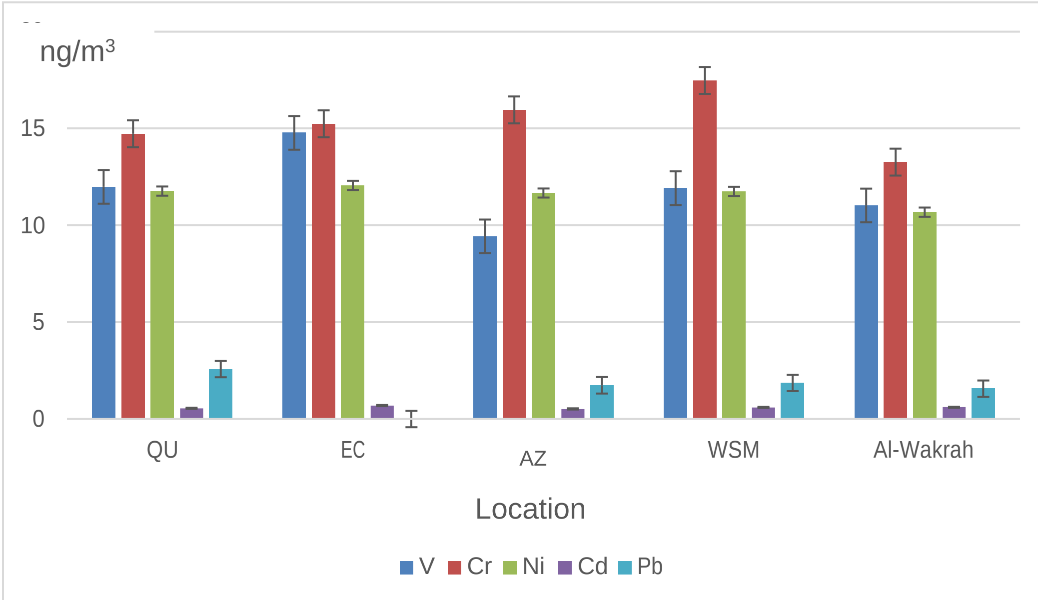

Figure 16. Average concentrations of heavy metals in PM2.5 collected from different sampling stations.

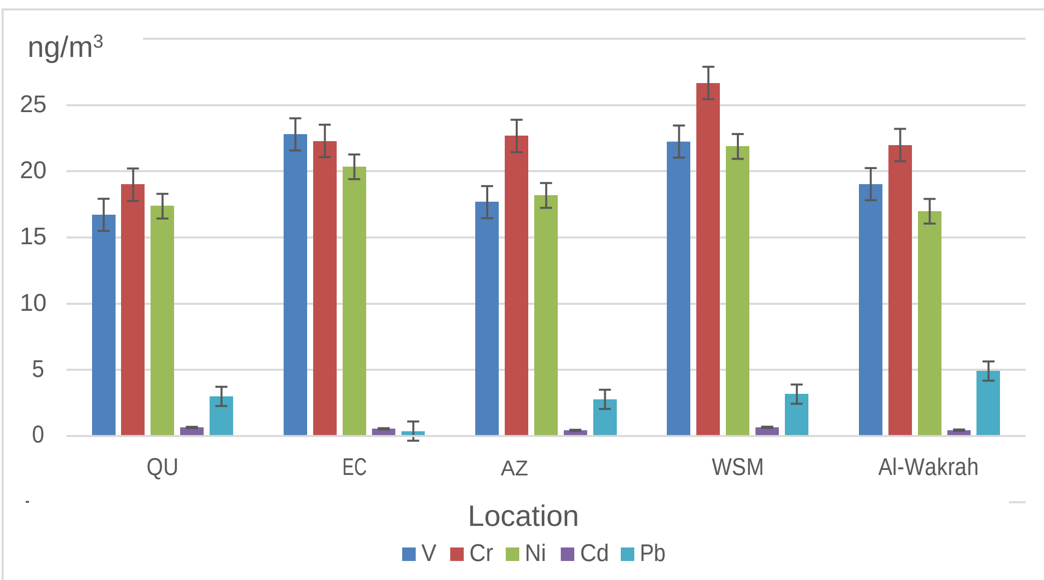

Figure 17. Average concentrations of heavy metals in PM10 samples collected from different sampling stations.

4.4 Possible sources of PMs based on Enrichment Factor Analysis

The enrichment factor (EF) analysis was used based on the concentration of individual elements in the air particulate samples compared with their concentrations in the crust (Rudnick and Gao, 2003). This analysis provides useful information in determining the sources of elements detected in PM samples. In this study, Al was used as a reference element assuming that Al will be present at low concentrations in air samples. Usually, high EF values indicate the origin of elements to be from non-crustal anthropogenic sources, while low EF values are indicative of earth-crust or soil as main source

In this study, the EF values were categorized into three main classes , for example, Fe and Mg are mainly crustal elements and have small EF values indicating the PM source as natural (Chan et al., 1997). The EF values ranging between 1-9 are indicative of non-anthropogenic sources like Fe, Na, Mg, Sr, Ba, and Li (Table 18). The EF values considered to be in the Moderate category range from 10 to 100. The elements in this category are Ni, Cr, and V which are recognized as anthropogenic sources, where Ni and V come from burning of fossil fuel (Zhang et al., 2009) and Cr is from industrial activity. The EF values higher than 100 are considered as significant anthropogenic sources, such as Zn, Cd, and Pb (Table 18).

The relatively high EF values for Zn, Cd, and Pb may be indication of significant anthropogenic contribution in both PM2.5 and PM10 samples collected in Qatar, even the elemental concentrations are lower than some of previous studies in the Middle East region.

Near to the results of EF were also reported in different areas (Jeddah city and Rabigh city) of Saudi Arabia where EF values of Pb and Cd were more than1500 for Pb and 8800 for Cd (Khodeir et al., 2012; Nayebare et al., 2016). This reported high EF values for Pb, Cd, and Zn trace the source of PM pollution to mainly traffic and industrial activities. It should be emphasized here that Pb and Cd are known to be highly toxic to humans, especially children. Therefore, a more comprehensive study including the collection of soil and more air samples needs to be carried out to determine the exact source of these two toxic metals in these locations.

Table 16

Enrichment Factor (EF) Values for elements determined in PM2.5 and PM10 samples ($\mu g/m^3$)

	PM2.5		PM10	
	Elemental Concentration (Average) (ng/m^3)	EF	Elemental Concentration (Average) (ng/m^3)	EF
Al	496.95	R.E*	2256.01	R.E*
Fe	526.89	2.20	2504.23	2.30
Na	485.74	2.76	1185.53	1.48
Mg	574.83	6.30	3509.11	8.47
Li	0.30	2.40	1.78	3.06
V	11.82	19.98	19.67	7.32
Cr	15.33	27.33	22.51	8.83
Mn	9.04	1.91	28.54	1.33
Ni	11.58	40.42	18.94	14.55
Zn	206.34	505.11	231.17	124.65
Sr	10.79	5.53	53.82	6.07
Cd	0.58	1072.65	0.53	215.96
Ba	15.03	5.78	57.56	4.88
Pb	1.93	933.34	2.83	301.56

*Reference element used in EF calculation.

CHAPTER V: CONCLUSION

The present study aimed at investigating PM pollution, chemical composition and source of PM and its impact on air quality at different locations in Qatar. The gravimetric measurements revealed that the four months average PM concentrations exceed the WHO and USEPA standards in some stations. The concentration of PM2.5 and PM10 in Qatar University, Education city, Aspire Zone, Whole Sale Market, and Al-Wakrah city were 50, 64, 55, 59, 57, 138, 156, 127, 185, and 160 $\mu g/m^3$, respectively. Overall, the mean concentrations of PM10 and PM2.5 were recorded as peak at Whole Sale Market (185 $\mu g/m^3$) and Education City (64 $\mu g/m^3$), respectively. Activities in these two stations were mainly industrial/trading (WSM) and construction in (EC). Having such concentration could be reduced after finishing the construction activities and more efficient of transportation management in industrial/trading areas. The Air Quality Index tool was also used in this study to categorize the health risk associated with different PM levels. The AQI values indicated that 37.5% and 25% days of "Moderate" air quality , "Unhealthy for Sensitive Group" air quality, and "Unhealthy" respectively. The concentrations of elements in PM samples were relatively low compared to previous studies. The enrichment factor analysis showed that high concentrations of Pb, Cd, and Zn were probably due to road traffic emission and activity relates to medium industrial activity near to WSM. The presence of these heavy metals may also influence the degraded air quality in the sampling area as confirmed by AQI values.

This study highlights the urgent need to establish a strategy for continuous monitoring and a reliable and real-time warning system to inform the public about the air quality in Qatar. It is important to note that this study is considered as a pilot study to determine air quality based on PM pollution in Qatar. The findings obtained here provide important data which can be used to assist government agencies to establish air quality management system. However, this study was limited in terms of sampling and chemical composition analysis. Hence, future plans should include specific studies in determining long term effects of exposure to PM pollution in Qatar. Examples of such studies might be epidemiological studies using health statistics and PM pollution data, inclusion of a larger sampling area, and measurement of various PM sizes (like PM1) and different chemical components of PMs, such as PAHs and ions.

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APPENDICES

Appendix A: Meteorological Data

Daily Average of Some Meteorological Data At Qatar University

Date	Mean Temperature degree celsius	Mean Dew Point degree celsius	Mean Relative Humidity percentage	Total Rain Fall millimeters	Mean Wind Speed meters per second	Maximum Wind Gust meters per second	Mean Wind Direction 360 degree rose
6/1/2016	33.1	8.7	26	0	5.3	26.4	320
6/2/2016	34.6	4.9	18	0	3.8	19.2	300
6/3/2016	34.4	8	22	0	1.8	15.3	350
6/4/2016	33.2	14.4	36	0	2.7	13.2	20
6/5/2016	32.3	12.7	34	0	1.4	10.7	60
6/6/2016	33.6	16.4	40	0	1.1	7.8	100
6/7/2016	35.6	11.2	25	0	1.6	44.5	290
6/8/2016	37.5	9.3	21	0	5.2	25.7	330
6/9/2016	36.6	8.6	22	0	6.2	31.6	330
6/10/2016	35.2	15.5	33	0	3.2	30.6	350
6/11/2016	38.3	10.7	23	0	4.3	29.6	340
6/12/2016	36.1	8.3	22	0	7	17.5	350
6/13/2016	34.2	9	24	0	6.5	23.3	320
6/14/2016	34.4	3.9	20	0	6.5	28	320
6/15/2016	35	9.1	27	0	4.7	49	330
6/16/2016	33.7	16.4	41	0	2.4	13.6	20
6/17/2016	34.6	15.3	35	0	3.5	20.4	0
6/18/2016	34.9	11.2	27	0	4	16	360
6/19/2016	35.9	13.3	33	0	5	22.7	340
6/20/2016	37.7	9.3	22	0	5.2	28	340
6/21/2016	37.3	10.1	24	0	5.2	22.2	340
6/22/2016	35.2	16.7	35	0	2.7	12.7	20
6/23/2016	34.6	16.6	36	0	2.4	18.1	30
6/24/2016	34.9	16.4	37	0	2	19.6	50
6/25/2016	35.3	16.9	37	0	2	9.8	80
6/26/2016	35.9	15.4	36	0	1.2	20.4	60
6/27/2016	39	9.5	21	0	2.5	24.5	330
6/28/2016	36.6	19.7	41	0	3	25.7	30
6/29/2016	34.7	22.8	53	0	1.6	15	90
6/30/2016	36.5	18.9	40	0	1.3	15.8	50
7/1/2016	39.7	13.2	25	0	4.9	30.6	330
7/2/2016	38	13.1	26	0	6.5	29.6	330
7/3/2016	37.6	13	26	0	6.3	28.8	330
7/4/2016	38.2	10.7	23	0	3.6	22.2	340
7/5/2016	36.8	18.2	38	0	2.7	18.4	330
7/6/2016	36.6	14.3	28	0	2.4	36.2	10

Appendix A: Meteorological Data

7/7/2016	37.2	14.5	29	0	2.6	13	340
7/8/2016	38.8	14	26	0	3.1	20.8	340
7/9/2016	39.7	11.7	22	0	4.9	22.7	320
7/10/2016	39.6	9.6	20	0	6	28.8	320
7/11/2016	39.1	10.7	22	0	5.9	24.5	340
7/12/2016	37.8	10	23	0	5.7	22.7	320
7/13/2016	37.9	11.2	24	0	4.3	30.6	320
7/14/2016	36.1	20	45	0	2.8	9.3	20
7/15/2016	35.8	22.2	49	0	2.3	19.6	30
7/16/2016	35.2	23.8	54	0	3	29.6	20
7/17/2016	36.6	23.4	50	0	2.6	23.9	30
7/18/2016	35.8	26.5	62	0	2.6	28.8	90
7/19/2016	38	22.7	43	0	2.4	20.8	110
7/20/2016	39	21.5	39	0	2	10.2	150
7/21/2016	36.6	25	52	0	2.5	35	90
7/22/2016	37.3	25.1	53	0	1.7	15.5	80
7/23/2016	37.7	23.3	47	0	3.1	31.6	320
7/24/2016	35.1	27.4	65	0	2.8	26.4	40
7/25/2016	36.7	28.5	64	0	2.9	11.6	90
7/26/2016	36.2	28.7	66	0	2.9	28.8	90
7/27/2016	35.6	27.6	64	0	2.4	11.5	80
7/28/2016	35.6	27.1	62	0	2.8	28	100
7/29/2016	35.8	26.9	61	0	2.7	9.1	110
7/30/2016	35.4	25.8	59	0	1.3	28.8	80
7/31/2016	35.6	26.2	59	0	1.9	22.2	90
8/1/2016	36.9	22.7	47	0	1.2	11.8	70
8/2/2016	38.7	18.8	37	0	1.7	20	300
8/3/2016	37.8	23.5	49	0	2.6	19.6	70
8/4/2016	35.8	27.1	62	0	2.4	10.4	70
8/5/2016	35.7	26.8	61	0	2.5	22.7	40
8/6/2016	36.3	24.5	54	0	1.5	22.2	50
8/7/2016	36.7	24.6	53	0	1.9	12	70
8/8/2016	36.8	22.9	53	0	1.6	20	60
8/9/2016	35.8	25.5	58	0	1.4	27.2	40
8/10/2016	36.5	22.5	49	0	1.8	16	30
8/11/2016	35.9	26	59	0	1.9	31.6	90
8/12/2016	35.7	27.8	64	0	2.3	10.8	70
8/13/2016	36.3	27	64	0	2	17.5	60
8/14/2016	37.9	23.1	49	0	1.4	17.1	230
8/15/2016	38.1	22.3	44	0	1.2	12.7	120
8/16/2016	37	23.8	49	0	1.3	25.1	30

Appendix A: Meteorological Data

8/17/2016	37.5	22	45	0	3.3	29.6	350
8/18/2016	36.7	22.9	48	0	1.5	9.5	70
8/19/2016	35.4	25.9	60	0	2	12.7	70
8/20/2016	35.5	25	57	0	1.4	30.6	60
8/21/2016	35.4	25.7	60	0	1.2	28.8	80
8/22/2016	35.3	27.4	65	0	1.9	19.2	110
8/23/2016	35.9	26.1	60	0	2	12	100
8/24/2016	36.4	23.5	53	0	2.1	24.5	70
8/25/2016	36.3	24.4	54	0	2.4	26.4	80
8/26/2016	36.5	23.3	53	0	1.9	12.7	100
8/27/2016	36.1	25.1	56	0	1.3	9.8	70
8/28/2016	35.5	25.3	58	0	2	32.6	80
8/29/2016	35.9	24.5	56	0	2	9.5	80
8/30/2016	35.9	24.1	55	0	1.5	20.8	100
8/31/2016	36.4	21.5	48	0	1.6	18.1	70
9/1/2016	37.7	20.9	43	0	2	31.6	140
9/2/2016	37.6	21.3	45	0	2.6	20	130
9/3/2016	35	28	68	0	2.4	35	80
9/4/2016	35	26.8	63	0	1.9	8.6	60
9/5/2016	35.9	26.4	60	0	2.1	14.8	30
9/6/2016	36.5	22	45	0	2.7	29.6	350
9/7/2016	35.3	21	45	0	3.9	16	360
9/8/2016	34.1	21.4	49	0	1.4	25.1	20
9/9/2016	33.3	20.4	48	0	1.6	18.4	70
9/10/2016	32.9	23.3	58	0	1.5	21.7	60
9/11/2016	32.5	23.1	59	0	1.5	29.6	60
9/12/2016	33	24	61	0	2	23.3	60
9/13/2016	33.1	23.4	59	0	1.5	25.1	90
9/14/2016	33.8	26.5	68	0	1.9	9.8	70
9/15/2016	33.7	24.9	62	0	1.2	18.1	70
9/16/2016	33.4	22.8	56	0	1.5	14	70
9/17/2016	34.5	18.8	46	0	1.3	14.4	70
9/18/2016	34.3	22.5	56	0	2.2	28.8	350
9/19/2016	34.2	22	52	0	2.4	18.4	40
9/20/2016	34.1	13.6	33	0	3.6	25.7	340
9/21/2016	33.2	18	43	0	3.2	36.2	360
9/22/2016	32.4	23	61	0	1.5	21.7	60
9/23/2016	33.6	21.6	55	0	2.4	20.8	330
9/24/2016	33.7	19.9	47	0	2.8	18.4	330
9/25/2016	33.2	17.8	44	0	3.8	25.7	330
9/26/2016	31.7	20.7	54	0	1.8	9.3	0

Appendix A: Meteorological Data

9/27/2016	30.7	24.2	69	0	1.3	10.1	80
9/28/2016	32.9	19.4	51	0	1.8	28.8	360
9/29/2016	33.5	16.2	42	0	4	31.6	320
9/30/2016	31	14.8	40	0	5.1	24.5	320
10/1/2016	30.2	14.5	41	0	3	14.4	330
10/2/2016	29.4	13.4	41	0	1.8	20.8	20
10/3/2016	29.5	13.4	41	0	1.8	12.7	330
10/4/2016	29.6	16.4	49	0	2.2	14	320
10/5/2016	29.4	14.8	47	0	2.1	20.4	290
10/6/2016	30	12.2	39	0	2.2	15.8	280
10/7/2016	29.4	14.3	48	0	1.4	18.8	40
10/8/2016	29.1	18.7	58	0	1.3	10.3	40
10/9/2016	30.1	18	56	0	1.4	22.2	20
10/10/2016	30.1	17.7	57	0	1.4	13.8	80
10/11/2016	30.7	8.7	35	0	2.5	25.7	300
10/12/2016	30	14.8	49	0	1.7	28.8	310
10/13/2016	30.2	17	50	0	3.2	25.1	320
10/14/2016	29.4	20	60	0	1.4	20.8	30
10/15/2016	30	13.3	44	0	1.6	15	300
10/16/2016	29.8	15.4	50	0	2.5	19.2	330
10/17/2016	28.4	18.7	58	0	1.8	10	70
10/18/2016	29	19.6	60	0	1.9	18.4	70
10/19/2016	29.4	19.3	58	0	0.8	28	100
10/20/2016	30	13.7	42	0	2	33.7	300
10/21/2016	29.5	15.3	49	0	2.6	12.8	330
10/22/2016	28.1	19.4	61	0	1.8	12.7	20
10/23/2016	27.9	20	65	0	1.4	10.1	0
10/24/2016	27.9	21.2	70	0	1.4	31.6	40
10/25/2016	27.9	21.4	72	0	1	28	100
10/26/2016	28.7	23.3	73	0	2	30.6	100
10/27/2016	28.4	20.9	66	0	1.6	15.3	60
10/28/2016	28.5	18.1	58	0	1	11.9	50
10/29/2016	28.2	13.6	48	0	1.3	14.6	310
10/30/2016	27.6	15.1	50	0	1.5	28	320
10/31/2016	27.8	19.4	64	0	0.9	8.9	80
11/1/2016	27.6	22	73	0	1.3	18.4	100
11/2/2016	28.7	21.2	65	0	2.2	9.8	100
11/3/2016	28.6	20.8	64	0	1.7	9.8	20
11/4/2016	27.2	17.1	57	0	2.9	7.6	330
11/5/2016	27.1	18.2	62	0	2.3	6.9	320
11/6/2016	27.8	15.7	58	0	0.7	3.9	360

Appendix A: Meteorological Data

11/7/2016	26.9	17.2	57	0	2.8	10.1	350
11/8/2016	25.1	10.6	42	0	4	11.9	330
11/9/2016	25	13.8	51	0	4.1	8.9	330
11/10/2016	25.3	14.8	54	0	3.3	8.4	330
11/11/2016	24.6	17.4	66	0	1.5	5	0
11/12/2016	25.1	18.8	70	0	1	5.6	30
11/13/2016	24.7	18.4	71	0	0.9	4.6	50
11/14/2016	24.4	18.4	73	0	0.6	3.2	350
11/15/2016	24.9	17.9	69	0	1.1	4.9	300
11/16/2016	24.5	15.6	63	0	0.5	3.5	90
11/17/2016	25	19.2	71	0	1.3	5.3	110
11/18/2016	24.7	17.5	66	0	0.6	4.3	50
11/19/2016	24.6	16.1	64	0	2.9	6.9	310
11/20/2016	24.5	16.3	62	0	3.6	8.2	320
11/21/2016	24	14.7	58	0	2.1	5.9	330
11/22/2016	23.8	16.7	65	0	0.9	5.3	30
11/23/2016	23.9	18.7	74	0	1	6.4	30
11/24/2016	25.2	17.9	65	0	2.1	7.1	60
11/25/2016	23.9	17.8	69	4.1	3.4	10.2	70
11/26/2016	22	18.6	81	3.6	2.7	8.2	40
11/27/2016	22.8	19.5	82	14.1	2.2	11.6	30
11/28/2016	23	18.6	77	0.1	2.6	6	330
11/29/2016	22.9	16.8	70	0	2.9	8.2	320
11/30/2016	23.3	16.6	67	0	1.8	4.7	340
12/1/2016	24.8	18.1	68	0	1.8	5.2	100
12/2/2016	25.6	20.6	76	0	2.5	6.6	120
12/3/2016	25.9	19.9	72	0	2.2	5.6	320
12/4/2016	24.7	18.7	71	0	4.2	9.5	330
12/5/2016	24	18.4	73	0	3.2	7.7	330
12/6/2016	23.7	20.3	82	0	1.5	3.9	350
12/7/2016	23.3	16.8	68	0	3.2	8.2	330
12/8/2016	21	13.2	63	0	4	8.3	310
12/9/2016	20.2	11	57	0	3.8	9.4	320
12/10/2016	17.3	5.4	49	0	4.5	10.8	310
12/11/2016	16.8	4.6	45	0	4.4	8.5	310
12/12/2016	17.6	6.4	48	0	4.6	9.6	310
12/13/2016	17.9	8.2	54	0	1.9	7.4	310
12/14/2016	19.8	11.7	61	0	1.8	6.2	130
12/15/2016	22.1	12.3	57	0	3.3	7.8	170
12/16/2016	18.4	9.6	58	0	3.8	9	330
12/17/2016	18.2	10.6	63	0	3.8	8.2	320

Appendix A: Meteorological Data

12/18/2016	18.7	11.5	64	0	3.7	9.3	320
12/19/2016	19.2	12	65	0	2.6	6.4	320
12/20/2016	20.2	12.4	63	0	1.6	4.7	210
12/21/2016	19.7	13	66	0	3.1	7.8	340
12/22/2016	20.2	13.3	66	0	2.2	6.4	340
12/23/2016	21.4	14.3	66	0	2.9	9.8	330
12/24/2016	21.1	16	74	0	2.1	5.6	350
12/25/2016	21.2	18.1	84	0	1.3	5.2	100
12/26/2016	20.3	17.9	87	0	1.3	3.9	80
12/27/2016	19.7	17.5	88	0	1	3.2	80
12/28/2016	21.8	14.6	68	0	1.7	4.9	290
12/29/2016	21	16.3	76	0	2.8	7.5	330
12/30/2016	21.7	15.6	72	0	1.9	4.7	330
12/31/2016	21.8	12.5	60	0	1.6	4.6	280
1/1/2017	23	11.4	55	0	2.4	5.2	300
1/2/2017	21.2	14.7	70	0	1.8	5.1	300
1/3/2017	20.2	14.1	71	0	1.8	4.1	310
1/4/2017	20.2	12	61	0	3.1	7.1	320
1/5/2017	18.4	9.6	58	0	5	10.8	320
1/6/2017	17.2	9.7	62	0	4.4	10.5	310
1/7/2017	18	11.8	69	0	1.8	4.7	320
1/8/2017	19.1	9.4	60	0	1.3	4	160
1/9/2017	20.8	13.4	66	0	2.2	5.9	130
1/10/2017	20.4	16.1	78	0	1.5	4.2	160
1/11/2017	19.4	14.3	75	0	1.6	4.6	310
1/12/2017	20.1	11.7	62	0	3.3	8.1	320
1/13/2017	18.5	9	56	0	3.7	8.3	310
1/14/2017	17.5	6	49	0	3.9	10.8	320
1/15/2017	17.6	9.6	61	0	1.8	4.5	310
1/16/2017	18.2	13	73	0	1.9	4.7	80
1/17/2017	18.4	10.7	62	0	3.2	7.5	330
1/18/2017	17.7	10.8	65	0	1.9	5.6	350
1/19/2017	19.1	13.7	71	0	2.2	5.9	110
1/20/2017	21	13.3	63	0	2.4	6.9	150
1/21/2017	19.5	15.1	77	0	1.5	5.6	310
1/22/2017	20.7	17	80	0	2	5.8	90
1/23/2017	19.3	9.6	55	0	4.2	9.1	340
1/24/2017	16.2	5.2	49	0	4.2	10.1	310
1/25/2017	17.1	8.4	58	0	2.6	7.3	320
1/26/2017	18.3	11.7	67	0	1.6	5.6	120
1/27/2017	20.2	12.1	62	0	3.3	9.9	150

Appendix A: Meteorological Data

1/28/2017	22.1	14.3	63	0	3.3	7.4	130
1/29/2017	20.5	12.8	62	0	3.5	9.6	350
1/30/2017	16.8	6.2	51	0	3.9	9.3	340
1/31/2017	17.2	10.8	67	0	1.6	4.8	80
2/1/2017	20.2	13.3	65	0	3.4	6.9	50
2/2/2017	15.2	3.2	45	0	5.8	11.8	340
2/3/2017	10.8	-2.4	42	0	6.2	14.7	310
2/4/2017	13	3.1	52	0	3.9	8.8	320
2/5/2017	13.5	2.9	50	0	2.1	6.6	310
2/6/2017	14.8	5.5	58	0.6	2.9	7.4	310
2/7/2017	15.6	5.9	54	0	3.5	9.3	310
2/8/2017	16.8	9.1	63	0	2.1	5.9	30
2/9/2017	18.2	13.4	74	0	1.5	6.2	90
2/10/2017	20	15	74	0	2.6	6.6	110
2/11/2017	19.6	14.6	74	0.3	3.1	8.7	50
2/12/2017	21.2	15.6	71	0.1	5.9	13.5	90
2/13/2017	21.1	16.9	77	4.2	3.3	11.2	110
2/14/2017	18.4	16.5	89	19.2	2.9	7.8	10
2/15/2017	20.4	18	86	7.4	4.2	10.1	100
2/16/2017	20.9	17.8	83	14.2	3.6	8.3	140
2/17/2017	19.5	16.2	81	11.7	3.8	9.1	360
2/18/2017	14.5	6.5	59	0	4.3	10.6	320
2/19/2017	12.6	4.7	59	0	4.3	11.3	320
2/20/2017	13.8	7	65	2.3	3.1	7.7	300
2/21/2017	14.9	7.7	63	0.6	2.4	6.1	300
2/22/2017	17.3	11.5	71	0	1.3	5	350
2/23/2017	18.5	14.2	77	0.2	2.3	6.2	70
2/24/2017	19.6	14.2	73	0.1	3.5	8.8	350
2/25/2017	19.6	12.9	67	0.8	2.1	8.5	350
2/26/2017	17.8	6.6	52	0.7	2.1	6	290
2/27/2017	18.3	6.2	51	0	2	6.3	300
2/28/2017	18	8	56	0	1.4	4.8	340

Appendix A: Meteorological Data

Daily Average of Some Meteorological Data At Alwakrah

Date	Mean Temperature degree celsius	Mean Dew Point degree celsius	Mean Relative Humidity percentage	Total Rain Fall millimetes	Mean Wind Speed meters per second	Maximum Wind Gust meters per second	Mean Wind Direction 360 degree rose
6/1/2016	33.2	7.8	23	0	6.2	13.7	320
6/2/2016	34.1	4.3	18	0	5.4	12	300
6/3/2016	32.6	14.9	39	0	2.5	8	130
6/4/2016	31.9	16.7	44	0	4.6	10.1	10
6/5/2016	31.1	17.2	45	0	2.3	6.5	50
6/6/2016	31.1	20.9	55	0	2.6	5.7	120
6/7/2016	32.5	18.1	46	0	2.5	6.2	160
6/8/2016	36.8	10.9	22	0	6.6	12.8	330
6/9/2016	37.7	5.9	16	0	7.5	13.4	330
6/10/2016	35.2	15.6	35	0	5.1	11.2	350
6/11/2016	36.5	13.9	29	0	5.9	12.3	340
6/12/2016	35.9	9.8	21	0	8.2	15.7	350
6/13/2016	34.8	5.9	18	0	7.3	13	320
6/14/2016	34.4	1.4	16	0	7.2	13.6	310
6/15/2016	33	14.7	40	0	6	12	340
6/16/2016	31.9	22.1	58	0	3.4	6.4	20
6/17/2016	32.8	19.3	46	0	5.8	11	0
6/18/2016	33.9	13.8	31	0	6.5	10.8	360
6/19/2016	34.1	17.8	40	0	6.1	10.5	360
6/20/2016	36.3	14.5	29	0	7	12.4	360
6/21/2016	34.9	16.3	35	0	6.5	14.5	360
6/22/2016	33.8	19.3	45	0	4.8	8.7	10
6/23/2016	33	20	49	0	3	7.1	20
6/24/2016	32.7	21.9	54	0	2.9	6.4	70
6/25/2016	32.9	21.6	53	0	2.9	6.8	50
6/26/2016	33.5	23.5	57	0	2.2	6.2	100
6/27/2016	36.4	16.8	35	0	3.2	8.7	350
6/28/2016	34.4	22.4	52	0	3.7	8.7	20
6/29/2016	32.8	25.5	66	0	2.8	6.4	90
6/30/2016	33.5	24.1	59	0	2.2	5.8	110
7/1/2016	39.2	14.4	25	0	6.4	13.7	330
7/2/2016	38.4	11.7	22	0	7	13.4	320
7/3/2016	37.1	13.3	25	0	7.4	15.5	340
7/4/2016	34.8	20.9	47	0	4.6	10.7	0
7/5/2016	34.6	21.6	52	0	3.5	8.7	340
7/6/2016	33.6	20.4	48	0	3.4	7	90

Appendix A: Meteorological Data

7/7/2016	34.7	19.7	46	0	3.5	8.4	360
7/8/2016	35.9	17.3	36	0	4	9	350
7/9/2016	39.4	9.9	19	0	5.6	12.3	320
7/10/2016	40	7.5	17	0	6.5	15.3	310
7/11/2016	39	10.3	19	0	7.3	14.7	340
7/12/2016	38.2	6.9	18	0	6.4	17	310
7/13/2016	37.4	11.4	23	0	5.4	11.6	320
7/14/2016	34.2	23	56	0	3.8	6.4	0
7/15/2016	33.9	26.6	67	0	3.6	8.1	40
7/16/2016	34.1	25.8	64	0	4.2	9.7	10
7/17/2016	34.6	25.5	62	0	3	9.5	80
7/18/2016	34.5	28.3	71	0	3.7	7.5	70
7/19/2016	35.6	28.5	67	0	3.8	6.3	100
7/20/2016	35.9	27.8	64	0	3.7	7.5	130
7/21/2016	35	27.7	67	0	4.6	8.9	90
7/22/2016	34.8	28.1	69	0	3.1	6.1	100
7/23/2016	35.6	26.7	63	0	4.7	8.9	360
7/24/2016	34.2	28.4	72	0	4.8	7.9	40
7/25/2016	35.4	28.8	69	0	4.1	9.2	100
7/26/2016	35	29.9	75	0	4.5	9.1	80
7/27/2016	34.6	28.8	72	0	4.3	7.1	80
7/28/2016	34.7	27.2	65	0	5	9	110
7/29/2016	34.9	26.9	64	0	4.4	7.6	110
7/30/2016	34.5	26.5	63	0	3	7.4	110
7/31/2016	34.7	27	65	0	3.6	6.2	90
8/1/2016	34.5	27.1	66	0	3.2	6.2	110
8/2/2016	36.2	24.2	53	0	3.4	6.7	130
8/3/2016	36.4	24.9	56	0	4.1	6.9	110
8/4/2016	35.4	27.8	65	0	4.3	8.7	60
8/5/2016	35	29.1	72	0	4.5	7.7	20
8/6/2016	35.3	26.1	60	0	3.2	9.2	40
8/7/2016	35.3	26.7	63	0	3.5	7.8	90
8/8/2016	35.1	27.1	65	0	3.6	6.4	70
8/9/2016	35	26.4	63	0	3.1	6	40
8/10/2016	35.2	24.7	58	0	3.9	7.6	20
8/11/2016	34.9	26.6	64	0	4.1	7.6	90
8/12/2016	35.2	28.9	70	0	3.8	9.7	70
8/13/2016	34.9	29.9	76	0	3.7	7.9	50
8/14/2016	35.8	27.3	63	0	3.3	5.6	130
8/15/2016	35.9	25	55	0	2.9	6.4	180
8/16/2016	35.7	25	55	0	3.1	7.9	10

Appendix A: Meteorological Data

8/17/2016	36	25.1	55	0	6.3	11.7	360
8/18/2016	35.7	25.4	56	0	3.7	6.9	50
8/19/2016	35.3	27.3	64	0	4.2	7.9	50
8/20/2016	35	26.5	62	0	3.3	6.7	50
8/21/2016	34.2	26.8	66	0	2.9	5.7	90
8/22/2016	34.7	28	69	0	3.7	8.2	120
8/23/2016	35.2	27.7	66	0	3.7	6.7	100
8/24/2016	35.9	25.8	58	0	4.6	12.5	100
8/25/2016	35.1	26.7	63	0	4.4	7.5	80
8/26/2016	35.3	26.8	62	0	3	5.6	90
8/27/2016	34.7	27.9	68	0	3.1	7.2	110
8/28/2016	34.7	26.4	63	0	4	8.5	90
8/29/2016	35.1	26.6	62	0	4	9.6	70
8/30/2016	35.3	26.2	60	0	3.8	8.2	100
8/31/2016	34.9	25.2	59	0	3.1	5.7	110
9/1/2016	35.6	24.3	57	0	3.8	6.4	170
9/2/2016	35.4	26.3	61	0	4	9.1	150
9/3/2016	34.8	28.3	69	0	4	7.1	70
9/4/2016	34.5	27.1	66	0	3.8	7.3	40
9/5/2016	35.3	26.5	61	0	4.1	8.9	10
9/6/2016	35.7	23.7	51	0	5.5	12.4	350
9/7/2016	34.8	22.9	51	0	7.1	12.9	0
9/8/2016	33.7	22.8	53	0	3.8	8.2	20
9/9/2016	32.8	21.6	52	0	3.3	7.3	60
9/10/2016	33.1	24.1	60	0	3.7	7.2	60
9/11/2016	32.2	24.1	63	0	2.6	7.1	40
9/12/2016	31.7	24.7	67	0	3.2	6.6	90
9/13/2016	32.4	24.7	65	0	3.4	7.1	80
9/14/2016	33.5	27.6	72	0	3.5	6.4	50
9/15/2016	33.3	26.3	67	0	2.9	5.3	60
9/16/2016	33.1	22.7	55	0	3	7.3	70
9/17/2016	33	22.8	57	0	2.5	4.8	100
9/18/2016	33.3	24.6	62	0	3.4	6.6	40
9/19/2016	33.9	23.4	55	0	3.7	8.6	10
9/20/2016	34	15.2	34	0	6	13	340
9/21/2016	32.4	21	51	0	5.9	10.7	350
9/22/2016	31.7	24.1	64	0	2.9	5.4	30
9/23/2016	32.6	22.7	58	0	4.3	8	330
9/24/2016	33.1	19.4	45	0	5.1	10	330
9/25/2016	33.7	15.9	37	0	6	12.7	320
9/26/2016	31.2	21.4	57	0	3.8	7.1	350

Appendix A: Meteorological Data

9/27/2016	30.5	24.6	71	0	2.6	6.3	60
9/28/2016	31.8	20.9	54	0	2.8	7	340
9/29/2016	32.9	17.6	43	0	6.2	12.9	330
9/30/2016	31	14	38	0	6.6	13	310
10/1/2016	29.8	16.6	46	0	5.7	10.1	350
10/2/2016	29	17	49	0	4.4	10.6	20
10/3/2016	28.7	16.3	48	0	4.8	9.3	350
10/4/2016	28.6	17.7	53	0	3.8	8.6	340
10/5/2016	28.1	16.5	52	0	2.8	6.7	320
10/6/2016	28.2	16.6	51	0	3.1	5.7	230
10/7/2016	29.5	16.9	50	0	3.8	6.6	30
10/8/2016	28.3	20	62	0	3	6.7	30
10/9/2016	29.2	20.7	62	0	2.6	5.8	80
10/10/2016	29	21.1	65	0	3	6	80
10/11/2016	29.8	12.7	42	0	3.3	9.7	290
10/12/2016	29	18.3	55	0	2.7	7.3	310
10/13/2016	29.6	18.8	54	0	4.5	9.8	340
10/14/2016	29	20.7	62	0	3.7	7.9	10
10/15/2016	28.8	17.9	56	0	2.6	6.7	250
10/16/2016	29.3	18.5	55	0	4.9	10.3	340
10/17/2016	28.8	19.7	59	0	3	5.8	60
10/18/2016	29.3	22.3	66	0	3.4	5.7	40
10/19/2016	29.7	21.4	62	0	2.4	4.9	90
10/20/2016							
10/21/2016							
10/22/2016							
10/23/2016	27.9	21.1	67	0	3	6.2	50
10/24/2016	27.7	21.8	71	0	3.2	5.2	0
10/25/2016	27.8	22.7	74	0	2.9	5.4	90
10/26/2016	29.2	23.7	72	0	3.7	6.3	90
10/27/2016	29.4	22.8	68	0	4.4	6.8	40
10/28/2016	28.8	20.9	63	0	3.3	5.9	30
10/29/2016	27.5	15.1	50	0	2.9	6.9	320
10/30/2016	27.5	16.2	54	0	3	7.2	310
10/31/2016	27.7	20.5	67	0	3.4	6.5	50
11/1/2016	28.7	21.9	67	0	3.1	5.9	80
11/2/2016	29.1	21.5	64	0	4.1	6.9	90
11/3/2016	28.5	21.7	67	0	4.2	9.2	40
11/4/2016	27	17.8	58	0	6	9.3	340
11/5/2016	27.2	16.6	57	0	4.2	8.6	300
11/6/2016	27.4	19.6	64	0	2.5	4.9	110

Appendix A: Meteorological Data

11/7/2016	26.6	18	60	0	5.4	12.8	350
11/8/2016	25.4	10.1	39	0	6.5	13.1	320
11/9/2016	25	12.7	48	0	5.7	9.9	310
11/10/2016	24.9	15.6	57	0	5.8	11.2	340
11/11/2016	25	17.9	65	0	4	7.5	350
11/12/2016	25.3	19.2	70	0	3.1	5.7	10
11/13/2016	24.7	18.8	70	0	2.5	5.3	30
11/14/2016	23.7	17.4	70	0	2.4	5	300
11/15/2016	23.7	19	76	0	2.4	5.5	250
11/16/2016	24.1	18.2	70	0	2.3	4.3	130
11/17/2016	26.1	19.1	65	0	3.5	4.9	120
11/18/2016	24.8	17.3	63	0	2.3	5.6	60
11/19/2016	24.1	14.7	60	0	5	8.9	300
11/20/2016	24.5	15.3	59	0	5.7	10	310
11/21/2016	24.1	15.9	61	0	4.5	8.1	340
11/22/2016	24.4	17.8	67	0	4	8.9	360
11/23/2016	25	19.2	70	0	3.1	7	40
11/24/2016	25.6	18.8	66	0.1	5.1	11.2	100
11/25/2016	24.2	18.3	70	0.5	7.1	12.8	80
11/26/2016	23.7	19.3	77	18	6.5	11.2	40
11/27/2016	24.2	19.2	74	11.6	3.4	15.3	40
11/28/2016	23.1	17.7	72	0	4.6	8.5	330
11/29/2016	22.8	15.5	64	0	5.2	9.8	310
11/30/2016	23.1	16.4	66	0	3.6	7.3	340
12/1/2016	24.1	18.6	72	0	3.2	5.8	120
12/2/2016	25	22.2	84	0	3.1	5.3	130
12/3/2016	25	20.9	79	0	3.6	8.7	350
12/4/2016	24.8	18	67	0	6	10.9	320
12/5/2016	24.2	17.9	69	0	4.9	10	340
12/6/2016	23.5	19.9	80	0	2.1	5.3	30
12/7/2016	22.8	16.9	70	0	5.5	9.7	330
12/8/2016	20.8	12.5	61	0	5.6	10	300
12/9/2016	20.7	10.4	53	0	5.6	10.3	310
12/10/2016	17.3	3.7	44	0	6.8	12.1	310
12/11/2016	16.5	3.5	43	0	5.9	11.2	300
12/12/2016	17.2	5.7	47	0	5.9	11	300
12/13/2016	17.4	8.1	55	0	2.9	6.6	310
12/14/2016	19.5	13.3	68	0	3.6	7.4	140
12/15/2016	21.1	14.6	67	0	5.3	9.8	180
12/16/2016	18.5	9.3	56	0	6	10.7	330
12/17/2016	18	9.9	60	0	5.8	9.3	310

Appendix A: Meteorological Data

12/18/2016	18.6	10.7	61	0	5.8	10.5	310
12/19/2016	18.9	11.8	64	0	4.1	8.1	320
12/20/2016	19.1	13.4	70	0	2.2	5.6	130
12/21/2016	19.3	13.2	68	0	6.1	11.4	340
12/22/2016	19.4	13.3	68	0	4.1	8.9	340
12/23/2016	20.6	14.7	69	0	5	9.9	330
12/24/2016	20.9	16.3	76	0	3.8	8	350
12/25/2016	19.2	17.5	90	0	1.4	3.6	90
12/26/2016	18.4	17.3	94	0	1.6	4.5	120
12/27/2016	17.7	8.4	55	0	1.4	3.1	40
12/28/2016	19.1	12.8	66	0	2.9	6.8	240
12/29/2016	20.6	16.1	76	0	4.5	8.7	340
12/30/2016	21.4	14.8	68	0	3.3	6.6	350
12/31/2016	21.4	12.6	61	0	2.9	6	280
1/1/2017	21.5	12	59	0	3.2	6.9	300
1/2/2017	20.3	16.1	77	0	2.5	6.3	280
1/3/2017	19.8	15.2	76	0	2.9	6.9	310
1/4/2017	19.6	12.1	62	0	5.2	9	320
1/5/2017	18.1	8.8	56	0	6.7	11.8	310
1/6/2017	16.8	8.9	60	0	6.5	11.1	310
1/7/2017	17.8	11.6	68	0	3.6	6.1	330
1/8/2017	19	11.6	63	0	2.6	4.8	150
1/9/2017	20.1	15.8	77	0	3.1	5.1	140
1/10/2017	19.8	17.2	85	0	2.4	4.2	140
1/11/2017	19.3	14.5	74	0	2.6	6.2	340
1/12/2017	19.9	10.4	57	0	5.7	9.5	300
1/13/2017	18.6	8.4	53	0	5.5	8.7	300
1/14/2017	17.6	5.4	46	0	5.8	12	320
1/15/2017	17.2	9.8	62	0	3.4	6.4	300
1/16/2017	18.5	13.5	73	0	2.8	5.2	80
1/17/2017	18.2	10.9	63	0	5.3	9.9	330
1/18/2017	17.6	10.9	66	0	3.6	8.4	350
1/19/2017	18.9	14	73	0	3.3	7	120
1/20/2017	19.9	14.7	73	0	3.6	7.4	150
1/21/2017	19.5	14.8	75	0	2.9	6.1	310
1/22/2017	20.6	17.5	82	0	3.5	7.1	90
1/23/2017	19.2	9.8	55	0	6.5	12.3	340
1/24/2017	15.9	4.3	47	0	6.6	11.3	310
1/25/2017	16.7	8.3	59	0	4.5	8.5	320
1/26/2017	18.3	12.2	68	0	3.1	6.2	110
1/27/2017	19.7	13.9	69	0	6.3	8.7	140

Appendix A: Meteorological Data

1/28/2017	20.6	16.1	76	0	5	8.1	120
1/29/2017	20	13.4	67	0	4.6	12	0
1/30/2017	16.6	6.2	51	0	6.4	12.7	340
1/31/2017	16.9	11.9	72	0	3.6	5.9	110
2/1/2017	19.6	14.7	74	0	4.3	10.9	40
2/2/2017	15.3	3.4	45	0	8.3	15.9	340
2/3/2017	10.8	-3.7	39	0	8.8	18.5	310
2/4/2017	13.1	2.5	49	0	6.3	10.9	300
2/5/2017	13.4	2.6	49	0	3.3	7.5	310
2/6/2017	14.3	5.8	58	0.3	4.9	9.5	320
2/7/2017	15.6	4.6	50	0	6.1	10.3	310
2/8/2017	17.3	11.1	68	0	3.5	10	20
2/9/2017	18.2	14.8	81	0	2.7	7.1	50
2/10/2017	18.7	16	84	0.1	2.4	4.1	110
2/11/2017	19.2	15.3	78	0.4	5.1	10	40
2/12/2017	20.1	16.5	80	0.2	7.5	15.4	80
2/13/2017	20.5	16.6	79	2	5	12.3	100
2/14/2017	18.7	16.3	86	7.1	5.8	11.1	20
2/15/2017	19.7	17.4	87	3.7	5.3	9.8	80
2/16/2017	19.9	17.3	85	8.9	5.4	13.3	120
2/17/2017	19.3	15.4	78	5	5.6	13.7	20
2/18/2017	14.6	5.3	54	0	6.2	12.5	320
2/19/2017	12.8	3.5	54	0	6.7	10.7	310
2/20/2017	13.5	5.7	60	1.9	5.3	9.8	300
2/21/2017	14.5	6.6	61	1.4	3.5	7	290
2/22/2017	16.7	12.1	74	0	2.6	6.1	50
2/23/2017	18.4	14.9	80	1.2	3.7	6.7	50
2/24/2017	19.1	14.2	74	0	6	12	360
2/25/2017	18.8	13.2	70	1.6	3.7	10.3	10
2/26/2017	17.4	6.9	52	0.1	2.8	9.8	330
2/27/2017	18.3	6.5	50	0	3.5	7.7	300
2/28/2017	17.5	10.4	64	0	3.3	6.7	350

Appendix A: Meteorological Data

Daily Average of Some Meteorological Data At Abuhamour

Date	Mean Temperature (degree celsius)	Mean Dew Point (degree celsius)	Mean Relative Humidity (percentage)	Total Rain Fall (millimeters)	Mean Wind Speed meters per second	Mean Wind Direction 360 degree rose
6/1/2016	33.9	5.5	20	0	3.9	320
6/2/2016	35.6	0.4	14	0	3	300
6/3/2016	35.9	3.3	14	0	1.9	0
6/4/2016	34.9	9.2	22	0	2.8	10
6/5/2016	34.6	7.6	22	0	1.6	40
6/6/2016	35.5	10.1	25	0	1.5	120
6/7/2016	36	9.6	24	0	1.9	160
6/8/2016	38.4	5	16	0	4	330
6/9/2016	37.5	4.1	16	0	4.8	320
6/10/2016	37.7	10.8	22	0	3.2	350
6/11/2016	39.3	8	17	0	4	340
6/12/2016	36.9	5.4	17	0	5.1	340
6/13/2016	35	5.1	18	0	4.7	320
6/14/2016	35.2	-1.2	14	0	4.6	310
6/15/2016	35.9	7.7	21	0	3.5	330
6/16/2016	35.6	12.4	28	0	2	10
6/17/2016	35.8	11.6	26	0	3.7	350
6/18/2016	36.1	7.7	20	0	3.8	350
6/19/2016	36.4	13.1	28	0	3.9	350
6/20/2016	38.4	7.7	18	0	4	340
6/21/2016	38.2	8	19	0	3.9	340
6/22/2016	36.9	12.6	24	0	3.1	10
6/23/2016	36.5	12.4	25	0	2.3	360
6/24/2016	36.8	12.5	25	0	2	30
6/25/2016	36.5	12.8	28	0	1.8	60
6/26/2016	37	12.5	27	0	1.3	70
6/27/2016	40.5	4.7	16	0	2.2	330
6/28/2016	37.9	15.7	30	0	2.6	20
6/29/2016	35.8	20.1	42	0	1.5	70

Appendix A: Meteorological Data

6/30/2016	36.8	19.4	40	0	1.8	80
7/1/2016	40.8	9.3	18	0	4.1	330
7/2/2016	38.7	9.7	20	0	4.9	320
7/3/2016	38.4	9.5	20	0	4.6	330
7/4/2016	39.2	8.8	18	0	3.1	350
7/5/2016	37.5	15.2	33	0	2.5	320
7/6/2016	37.5	11.3	24	0	2.2	340
7/7/2016	37.9	12.4	26	0	2.5	330
7/8/2016	39.5	10.4	21	0	2.6	340
7/9/2016	40.8	7.3	16	0	3.1	320
7/10/2016	40.4	4.9	15	0	4.4	310
7/11/2016	40	6.9	16	0	4	330
7/12/2016	38.6	5.2	16	0	4.4	310
7/13/2016	38.9	6.6	17	0	3.4	310
7/14/2016	37.7	15.9	33	0	2.3	0
7/15/2016	37.4	19.1	37	0	2	10
7/16/2016	36.7	21.8	44	0	2.7	0
7/17/2016	38.1	19.4	38	0	2.2	20
7/18/2016	37.3	23.8	49	0	2.3	80
7/19/2016	38.9	21.7	40	0	2.2	110
7/20/2016	39.8	18.9	34	0	1.8	150
7/21/2016	37.7	22.4	43	0	2.3	90
7/22/2016	38	23.6	47	0	1.9	80
7/23/2016	38.5	22	42	0	2.5	350
7/24/2016	36.3	25.4	55	0	2.7	30
7/25/2016	37.5	26.4	55	0	2.5	100
7/26/2016	37.2	26.7	56	0	2.6	80
7/27/2016	36.3	26	57	0	2.7	80
7/28/2016	35.9	25.5	55	0	2.7	100
7/29/2016	36.4	25.1	53	0	2.6	110
7/30/2016	36	24.4	52	0	2	90
7/31/2016	36.3	24.1	51	0	1.9	100
8/1/2016	37.3	22	45	0	1.7	90
8/2/2016	39	17.5	35	0	1.6	250
8/3/2016	38.7	20.2	40	0	2.5	60

Appendix A: Meteorological Data

8/4/2016	37.1	25	51	0	2.6	50
8/5/2016	36.9	26.2	56	0	2.5	20
8/6/2016	37.4	22.2	45	0	1.8	30
8/7/2016	37.3	22.7	47	0	2	90
8/8/2016	37.6	21	46	0	1.8	70
8/9/2016	37.3	23.2	47	0	1.8	10
8/10/2016	37.4	21	44	0	2.4	10
8/11/2016	36.7	24.1	52	0	2.2	80
8/12/2016	36.7	26.8	58	0	2.2	70
8/13/2016	37.4	25.9	56	0	2.2	60
8/14/2016	38.1	22.5	47	0	1.8	110
8/15/2016	39	19.9	37	0	1.3	200
8/16/2016	38.7	21	39	0	1.9	340
8/17/2016	38.3	20.9	39	0	3.4	340
8/18/2016	37.9	19.7	38	0	2.1	60
8/19/2016	37	23.8	49	0	2.3	40
8/20/2016	37.1	23.7	49	0	1.9	50
8/21/2016	36.2	24.3	52	0	1.7	70
8/22/2016	36.1	25.8	57	0	2.1	110
8/23/2016	36.7	23.5	52	0	2.3	100
8/24/2016	37.9	20.3	43	0	1.9	110
8/25/2016	37	22.1	48	0	2.1	80
8/26/2016	37.8	21.3	45	0	1.9	90
8/27/2016	37.1	23.7	49	0	1.8	100
8/28/2016	36.4	23.6	51	0	2.1	70
8/29/2016	37.1	21.6	45	0	2.3	70
8/30/2016	37.7	20.8	42	0	2	80
8/31/2016	36.9	20.4	44	0	1.9	90
9/1/2016	37.4	18.9	44	0	1.9	150
9/2/2016	37.7	20.5	42	0	2.3	130
9/3/2016	36	26.8	60	0	2.4	60
9/4/2016	36.4	24.7	52	0	2.1	50
9/5/2016	37.6	23	46	0	2.1	350
9/6/2016	37.5	20.8	40	0	3	350
9/7/2016	36.1	20.8	42	0	4	360

Appendix A: Meteorological Data

9/8/2016	35.4	19.6	41	0	1.8	10
9/9/2016	34.4	18.2	41	0	1.8	50
9/10/2016	34.2	22.5	51	0	2.1	60
9/11/2016	33.7	22.2	52	0	1.8	30
9/12/2016	33.4	23.2	57	0	1.9	70
9/13/2016	34	22.5	53	0	1.7	70
9/14/2016	35.2	25	58	0	1.8	60
9/15/2016	35	23.7	54	0	1.9	70
9/16/2016	34.7	20.1	45	0	1.5	50
9/17/2016	35	18.7	43	0	1.4	100
9/18/2016	35.6	20.4	48	0	2.2	350
9/19/2016	35.6	19.6	42	0	2.8	20
9/20/2016	35.2	11.7	28	0	3.7	330
9/21/2016	33.9	17.3	39	0	3.5	360
9/22/2016	33.4	21.6	53	0	1.7	20
9/23/2016	34.6	19.5	48	0	2.3	320
9/24/2016	34.8	17.2	38	0	2.7	340
9/25/2016	34.3	15.2	36	0	3.4	320
9/26/2016	33	19.4	46	0	1.9	360
9/27/2016	32.2	22.9	59	0	1.3	70
9/28/2016	34.6	16.7	38	0	1.7	340
9/29/2016	34.3	14.6	36	0	3.7	320
9/30/2016	31.5	13.6	36	0	4.2	310
10/1/2016	31.1	13.9	37	0	2.9	340
10/2/2016	30.7	12.7	35	0	2.5	10
10/3/2016	29.7	13.1	38	0	2	330
10/4/2016	30.4	15	42	0	2.1	330
10/5/2016	29.9	11.2	39	0	1.6	300
10/6/2016	30.8	8.9	32	0	1.9	280
10/7/2016	31.2	9.5	35	0	1.6	10
10/8/2016	30.6	15.4	44	0	1.5	10
10/9/2016	31.5	13.2	44	0	1.5	10
10/10/2016	31.4	13.6	45	0	1.5	70
10/11/2016	32.5	2.4	25	0	2.2	290
10/12/2016	32	9.7	34	0	1.9	310

Appendix A: Meteorological Data

10/13/2016	31.2	14.5	41	0	2.7	320
10/14/2016	30.5	17.4	48	0	2.3	10
10/15/2016	31.3	9.8	35	0	1.6	300
10/16/2016	31.1	13	41	0	2.8	320
10/17/2016	29.6	17.5	50	0	1.8	60
10/18/2016	30.7	17.4	48	0	2	60
10/19/2016	30.7	16.4	48	0	1.1	100
10/20/2016	31.3	11	33	0	1.8	310
10/21/2016	30.3	14.3	43	0	2.7	330
10/22/2016	29.6	17.7	50	0	2.1	360
10/23/2016	28.8	18.5	56	0	1.6	340
10/24/2016	29.3	19.8	60	0	1.9	20
10/25/2016	29	20.5	63	0	1.5	110
10/26/2016	29.9	22.3	65	0	2.2	90
10/27/2016	30.8	19	52	0	2.3	40
10/28/2016	30.5	15	45	0	1.9	10
10/29/2016	29.5	12	41	0	1.7	300
10/30/2016	29	13.9	43	0	1.5	330
10/31/2016	29.1	18.7	58	0	1.4	40
11/1/2016	29	21.4	64	0	1.3	90
11/2/2016	29.4	20.5	59	0	2	110
11/3/2016	29.6	20	58	0	2.2	20
11/4/2016	28.1	16.4	52	0	2.7	330
11/5/2016	28.1	17.1	56	0	2.5	320
11/6/2016	28.7	15	52	0	1.3	340
11/7/2016	27.3	16.7	54	0	3.1	340
11/8/2016	25.7	10	38	0	4.1	320
11/9/2016	25.6	13	47	0	3	320
11/10/2016	26.2	14.1	49	0	3	330
11/11/2016	26.3	16.7	57	0	2.1	0
11/12/2016	26.9	16.9	58	0	1.8	0
11/13/2016	25.7	17.6	64	0	1.4	360
11/14/2016	25.3	16.6	63	0	1.3	310
11/15/2016	25.7	17.6	64	0	1.2	300
11/16/2016	25.3	16.2	61	0	1	80

Appendix A: Meteorological Data

11/17/2016	25.8	18.2	65	0	1.4	130
11/18/2016	25.8	16.4	58	0	1	40
11/19/2016	25.1	14.7	58	0	2.3	310
11/20/2016	24.9	15.8	59	0	3.2	310
11/21/2016	25	14.5	54	0	2.3	330
11/22/2016	25	17.1	62	0	1.9	360
11/23/2016	25.6	18.9	67	0	1.6	10
11/24/2016	25.7	17.7	63	0	2.2	60
11/25/2016	24.6	17.4	64	0	3.1	70
11/26/2016	23	18.8	78	36.3	2.9	30
11/27/2016	23.9	19.3	76	3.9	1.7	20
11/28/2016	23.8	17.9	70	0	2.3	330
11/29/2016	23.6	16.4	65	0	2.6	320
11/30/2016	24.1	16.1	62	0	1.8	340
12/1/2016	25.1	17.8	66	0	1.5	120
12/2/2016	26	20.8	76	0	2	120
12/3/2016	26	20.4	74	0	1.9	330
12/4/2016	25.1	18.6	68	0	3.7	320
12/5/2016	24.7	18.2	70	0	3.1	320
12/6/2016	24.7	20.3	78	0	1.4	350
12/7/2016	25	18.1	67	0	2.1	330
12/8/2016	21.7	12.4	57	0	3	310
12/9/2016	21	10.5	53	0	3.2	320
12/10/2016	17.7	4.2	44	0	4	310
12/11/2016	17.2	3	40	0	3.4	300
12/12/2016	18	5.3	44	0	3.6	310
12/13/2016	18.7	7.2	48	0	1.6	310
12/14/2016	20.2	11.9	60	0	1.6	140
12/15/2016	22.1	12.2	56	0	3.1	160
12/16/2016	18.8	9.3	55	0	3.2	330
12/17/2016	18.6	10.2	59	0	3.1	320
12/18/2016	18.9	11.2	62	0	3.2	320
12/19/2016	19.8	11.6	60	0	2.1	310
12/20/2016	20.4	11.7	60	0	1.5	140
12/21/2016	20.3	12.9	63	0	3	340

Appendix A: Meteorological Data

12/22/2016	20.6	12.9	63	0	2.5	350
12/23/2016	21.9	13.7	63	0	2.6	330
12/24/2016	22.1	15.8	69	0	1.8	350
12/25/2016	21.6	18	81	0	1.2	100
12/26/2016	20.6	17.5	84	0	1.1	100
12/27/2016	19.7	17	86	0	0.9	100
12/28/2016	21.6	14.5	69	0	1.7	290
12/29/2016	22	16.2	71	0	2.7	330
12/30/2016	22.8	14.8	65	0	1.9	340
12/31/2016	23.2	11.3	53	0	1.3	300
1/1/2017	23.9	9.9	48	0	2.4	300
1/2/2017	22.1	14.5	65	0	1.6	310
1/3/2017	21.3	13.7	66	0	1.6	310
1/4/2017	20.3	11.6	59	0	2.8	320
1/5/2017	18.7	9.2	55	0	4.1	320
1/6/2017	17.5	9	58	0	3.5	310
1/7/2017	19.1	11.4	62	0	1.6	340
1/8/2017	19.6	8.7	55	0	1.1	70
1/9/2017	20.9	12.6	64	0	2	130
1/10/2017	21.1	16.6	78	0	1.3	140
1/11/2017	20.7	13.4	65	0	1.6	310
1/12/2017	20.5	10.8	57	0	3	320
1/13/2017	19.1	8.5	52	0	2.9	310
1/14/2017	18	5.6	46	0	3	320
1/15/2017	17.9	8.9	57	0	1.5	330
1/16/2017	19.6	12.8	66	0	1.4	80
1/17/2017	19.2	10.5	59	0	2.6	320
1/18/2017	18.6	10.8	62	0	1.5	350
1/19/2017	19.4	13.3	68	0	1.8	120
1/20/2017	21.7	12.6	59	0	2.1	140
1/21/2017	20.4	14.8	71	0	1.4	310
1/22/2017	21.6	16.6	73	0	2.1	90
1/23/2017	19.8	9.3	53	0	3.9	330
1/24/2017	16.6	4.6	46	0	3.7	310
1/25/2017	17.7	8.3	55	0	2.3	330

Appendix A: Meteorological Data

1/26/2017	18.9	11.2	63	0	1.7	120
1/27/2017	20.3	11.9	61	0	2.8	140
1/28/2017	22.1	14.1	63	0	2.8	120
1/29/2017	21.4	12.8	59	0	3	340
1/30/2017	17.4	5.6	48	0	3.1	330
1/31/2017	17.8	10.6	64	0	1.6	90
2/1/2017	21	12.6	61	0	2.9	20
2/2/2017	15.6	2.7	42	0	5.3	330
2/3/2017	11.1	-3.9	38	0	5.4	310
2/4/2017	13.4	2.7	49	0	3.3	310
2/5/2017	14.5	1.9	44	0	2	310
2/6/2017	15.1	4.1	53	0.7	2.6	320
2/7/2017	16.3	4.8	49	0	3	320
2/8/2017	18.1	7.7	54	0	2	10
2/9/2017	19.2	13.3	70	0	1.6	90
2/10/2017	20.8	14.9	71	0	2	110
2/11/2017	20.4	14.5	69	0.3	3.2	40
2/12/2017	21.3	16.5	74	0.4	5.4	80
2/13/2017	21.9	17.2	75	2.9	3	100
2/14/2017	19.2	17.3	89	12.8	3.3	10
2/15/2017	20.8	18.4	87	6.2	3.3	80
2/16/2017	21	18.3	85	14.7	3.2	120
2/17/2017	19.8	16.1	80	11.5	3.3	10
2/18/2017	15	5.3	53	0	4.1	320
2/19/2017	13.2	3.8	54	0	3.5	320
2/20/2017	14.1	6	60	3.2	2.6	300
2/21/2017	15.4	6.6	58	1.8	2.2	290
2/22/2017	18.1	11.1	66	0	1.6	350
2/23/2017	19.4	14.9	76	0.3	2.4	60
2/24/2017	20.2	14.2	70	0	3.5	350
2/25/2017	20	12.6	63	1.6	2.2	340
2/26/2017	18.3	5.9	47	0.4	1.9	290
2/27/2017	19.8	3.7	40	0	1.9	300
2/28/2017	19.5	5.9	46	0	1.3	340

Appendix B: PM Calculations

$$Q_{act} = F_i + F_f / 2$$

Where: Q_{act} = Average sampling flow rate at field sampling conditions

F_i = Initial actual flow rate (m^3/min)

F_f = Final actual flow rate (m^3/min)

$$V_{act} = Q_{act} \text{ x Sampling period}$$

Vact = Volume of sampled air (m^3)

To calculate PM concentration:

$TSP = (W_f - W_i) \text{ x } 10^6 / V_{act}$

Where:

TSP = mass concentration of total suspended particulate matter (µg/m^3)

W_f = Initial weight of clean filter (g)

W_i = Final weight of exposed filter (g)

10^6 = Conversion from g to µg

To calculate actual PM concentration at field condition:

$TSP_{std} = TSP_{act} (P_{std} / P_{act}) (T_{act} / T_{std})$

TSP_{act} = Actual concentration of PM at field conditions (µg/m^3)

TSP_{std} = Concentration at standard conditions (µg/m^3)

P_{act} = Average barometric pressure at the field during sampling (mm Hg)

P_{std} = 760 mm Hg

T_{act} = Average ambient temperature at the field conditions during the sampling period (K)

T_{std} = 298 K

Appendix C: Statistical Analysis

THE ANOVA MODEL FITTED IS: $Y_i=\beta_0+\beta_1 SAMP\_DATE+\beta_2 STATION+\beta_3 SAMP\_DATExSTATION+\varepsilon_i$

WHERE Y_i IS THE READING OF THE iTH ELEMENT

```
                                    The SAS System       14:45 Friday, October 6, 2017   1
                                  The GLM Procedure
                               Class Level Information
                         Class          Levels    Values
                         Samp_Date           4    1 2 3 4
                         Station             5    1 2 3 4 5
                             Number of observations    60

NOTE: Due to missing values, only 45 observations can be used in this analysis.

                                    The SAS System       14:45 Friday, October 6, 2017   2
                                  The GLM Procedure
Dependent Variable: PM25   PM25
                                         Sum of
      Source                   DF       Squares     Mean Square    F Value    Pr > F
      Model                    19    22965.98953     1208.73629       3.86    0.0010
      Error                    25     7833.22551      313.32902
      Corrected Total          44    30799.21503

                       R-Square     Coeff Var      Root MSE     PM25 Mean
                       0.745668      30.03388      17.70110      58.93711

      Source                   DF     Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                 3    7598.74765     2532.91588       8.08    0.0006
      Station                   4    1154.69557      288.67389       0.92    0.4672
      Samp_Date*Station        12   14212.54631     1184.37886       3.78    0.0024


      Source                   DF   Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                 3    8255.42007     2751.80669       8.78    0.0004
      Station                   4     687.86820      171.96705       0.55    0.7016
      Samp_Date*Station        12   14212.54631     1184.37886       3.78    0.0024

                                    The SAS System       14:45 Friday, October 6, 2017   3
                                  The GLM Procedure
                                 Least Squares Means
                       Adjustment for Multiple Comparisons: Tukey-Kramer
                                                    LSMEAN
                        Samp_Date     PM25 LSMEAN      Number
                        1              36.8070000          1
                        2              66.0682778          2
                        3              72.8567062          3
                        4              54.5246667          4


                          Least Squares Means for effect Samp_Date
                            Pr > |t| for H0: LSMean(i)=LSMean(j)
                                 Dependent Variable: PM25
                  i/j           1            2            3            4
                     1                   0.0056       0.0003       0.1308
                     2       0.0056                   0.7938       0.4621
                     3       0.0003       0.7938                   0.0783
                     4       0.1308       0.4621       0.0783


                         The SAS System        14:45 Friday, October 6, 2017   4
                                  The GLM Procedure
                                 Least Squares Means
                       Adjustment for Multiple Comparisons: Tukey-Kramer
                                                   LSMEAN
                         Station     PM25 LSMEAN      Number
                         1           56.3333828          1
                         2           55.4754167          2
                         3           58.8454167          3
                         4           64.2821699          4
                         5           52.8844274          5

                            Least Squares Means for effect Station
                             Pr > |t| for H0: LSMean(i)=LSMean(j)
                                 Dependent Variable: PM25
           i/j          1            2            3            4            5
              1                   1.0000       0.9983       0.8793       0.9944
              2       1.0000                   0.9944       0.8230       0.9980
              3       0.9983       0.9944                   0.9637       0.9538
              4       0.8793       0.8230       0.9637                   0.6475
              5       0.9944       0.9980       0.9538       0.6475

                                    The SAS System       14:45 Friday, October 6, 2017   5
```

Appendix C: Statistical Analysis

The GLM Procedure

Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

The SAS System 14:45 Friday, October 6, 2017 6

The GLM Procedure

Dependent Variable: Al Al

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	1434050.142	75476.323	8.79	<.0001
Error	40	343567.439	8589.186		
Corrected Total	59	1777617.581			

R-Square	Coeff Var	Root MSE	Al Mean
0.806726	34.88243	92.67786	265.6863

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	144918.374	48306.125	5.62	0.0026
Station	4	275501.076	68875.269	8.02	<.0001
Samp_Date*Station	12	1013630.692	84469.224	9.83	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	144918.374	48306.125	5.62	0.0026
Station	4	275501.076	68875.269	8.02	<.0001
Samp_Date*Station	12	1013630.692	84469.224	9.83	<.0001

The SAS System 14:45 Friday, October 6, 2017 7

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Samp_Date	Al LSMEAN	LSMEAN Number
1	310.700000	1
2	221.193333	2
3	212.250667	3
4	318.601333	4

Least Squares Means for effect Samp_Date

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Al

i/j	1	2	3	4
1		0.0543	0.0289	0.9954
2	0.0543		0.9934	0.0312
3	0.0289	0.9934		0.0160
4	0.9954	0.0312	0.0160	

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The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Station	Al LSMEAN	LSMEAN Number
1	182.445000	1
2	260.661667	2
3	321.908333	3
4	360.225000	4
5	203.191667	5

Least Squares Means for effect Station

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Al

i/j	1	2	3	4	5
1		0.2541	0.0058	0.0003	0.9815
2	0.2541		0.4946	0.0836	0.5566
3	0.0058	0.4946		0.8480	0.0251
4	0.0003	0.0836	0.8480		0.0015
5	0.9815	0.5566	0.0251	0.0015	

Appendix C: Statistical Analysis

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The GLM Procedure

Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

The SAS System 14:45 Friday, October 6, 2017 10

The GLM Procedure

Dependent Variable: Ca Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	37859671.6	1992614.3	0.94	0.5454
Error	40	84994409.3	2124860.2		
Corrected Total	59	122854081.0			

R-Square	Coeff Var	Root MSE	Ca Mean
0.308168	48.14009	1457.690	3028.017

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	6390577.65	2130192.55	1.00	0.4017
Station	4	13921555.90	3480388.97	1.64	0.1836
Samp_Date*Station	12	17547538.10	1462294.84	0.69	0.7526

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	6390577.65	2130192.55	1.00	0.4017
Station	4	13921555.90	3480388.97	1.64	0.1836
Samp_Date*Station	12	17547538.10	1462294.84	0.69	0.7526

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The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Samp_Date	Ca LSMEAN	LSMEAN Number
1	3548.40000	1
2	2815.26667	2
3	2697.20000	3
4	3051.20000	4

Least Squares Means for effect Samp_Date

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ca

i/j	1	2	3	4
1		0.5206	0.3906	0.7868
2	0.5206		0.9961	0.9705
3	0.3906	0.9961		0.9096
4	0.7868	0.9705	0.9096	

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The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Station	Ca LSMEAN	LSMEAN Number
1	2416.25000	1
2	2776.91667	2
3	3087.50000	3
4	3875.00000	4
5	2984.41667	5

Least Squares Means for effect Station

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ca

i/j	1	2	3	4	5
1		0.9733	0.7909	0.1228	0.8734
2	0.9733		0.9846	0.3629	0.9967
3	0.7909	0.9846		0.6786	0.9998
4	0.1228	0.3629	0.6786		0.5707
5	0.8734	0.9967	0.9998	0.5707	

Appendix C: Statistical Analysis

```
                    The SAS System       14:45 Friday, October 6, 2017 13
                  The GLM Procedure
               Class Level Information
         Class          Levels    Values
         Samp_Date           4    1 2 3 4
         Station             5    1 2 3 4 5
             Number of observations    60

                    The SAS System       14:45 Friday, October 6, 2017 14
                  The GLM Procedure
Dependent Variable: Na   Na
                                     Sum of
      Source                  DF          Squares     Mean Square    F Value    Pr > F
      Model                   19       3496804.53       184042.34       0.84    0.6509
      Error                   40       8767220.61       219180.52
      Corrected Total         59      12264025.14

                R-Square     Coeff Var      Root MSE       Na Mean
                0.285127      166.6504      468.1672      280.9277

      Source                  DF        Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3      1345329.086      448443.029       2.05    0.1228
      Station                  4       327065.641       81766.410       0.37    0.8264
      Samp_Date*Station       12      1824409.807      152034.151       0.69    0.7476

      Source                  DF      Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3      1345329.086      448443.029       2.05    0.1228
      Station                  4       327065.641       81766.410       0.37    0.8264
      Samp_Date*Station       12      1824409.807      152034.151       0.69    0.7476

                    The SAS System       14:45 Friday, October 6, 2017 15
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                         LSMEAN
        Samp_Date       Na LSMEAN      Number
        1              530.946667           1
        2              261.220000           2
        3              154.173333           3
        4              177.370667           4

         Least Squares Means for effect Samp_Date
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                  Dependent Variable: Na
     i/j           1              2              3              4
        1                    0.4025         0.1396         0.1810
        2       0.4025                      0.9230         0.9608
        3       0.1396       0.9230                        0.9991
        4       0.1810       0.9608         0.9991

                    The SAS System       14:45 Friday, October 6, 2017 16
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                       LSMEAN
         Station       Na LSMEAN      Number
         1            185.224167           1
         2            374.330833           2
         3            230.225000           3
         4            255.483333           4
         5            359.375000           5

          Least Squares Means for effect Station
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                  Dependent Variable: Na
i/j           1              2              3              4              5
   1                    0.8585         0.9993         0.9959         0.8909
   2       0.8585                      0.9421         0.9707         1.0000
   3       0.9993       0.9421                        0.9999         0.9605
   4       0.9959       0.9707         0.9999                        0.9821
   5       0.8909       1.0000         0.9605         0.9821
```

Appendix C: Statistical Analysis

```
                    The SAS System       14:45 Friday, October 6, 2017 17
                  The GLM Procedure
               Class Level Information
         Class          Levels    Values
         Samp_Date           4    1 2 3 4
         Station             5    1 2 3 4 5
             Number of observations    60
                    The SAS System       14:45 Friday, October 6, 2017  18

                  The GLM Procedure
Dependent Variable: Mg   Mg
                                        Sum of
      Source                  DF       Squares     Mean Square    F Value    Pr > F
      Model                   19    1296727.676      68248.825       2.19    0.0183
      Error                   40    1245752.652      31143.816
      Corrected Total         59    2542480.328

                 R-Square     Coeff Var      Root MSE       Mg Mean
                 0.510025      53.23480      176.4761      331.5052

      Source                  DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3     396543.0896     132181.0299       4.24    0.0108
      Station                  4     264266.5841      66066.6460       2.12    0.0960
      Samp_Date*Station       12     635918.0028      52993.1669       1.70    0.1031

      Source                  DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3     396543.0896     132181.0299       4.24    0.0108
      Station                  4     264266.5841      66066.6460       2.12    0.0960
      Samp_Date*Station       12     635918.0028      52993.1669       1.70    0.1031

                    The SAS System       14:45 Friday, October 6, 2017 19
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                         LSMEAN
        Samp_Date       Mg LSMEAN       Number
        1              465.553333           1
        2              286.806667           2
        3              251.633333           3
        4              322.027333           4

         Least Squares Means for effect Samp_Date
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                  Dependent Variable: Mg

  i/j           1             2             3             4
     1                     0.0401        0.0100        0.1333
     2       0.0401                      0.9471        0.9469
     3       0.0100        0.9471                      0.6962
     4       0.1333        0.9469        0.6962

                    The SAS System       14:45 Friday, October 6, 2017 20
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                        LSMEAN
         Station        Mg LSMEAN      Number
         1             235.825833          1
         2             346.516667          2
         3             371.425000          3
         4             423.358333          4
         5             280.400000          5

          Least Squares Means for effect Station
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                  Dependent Variable: Mg
 i/j           1             2             3             4             5
    1                     0.5457        0.3433        0.0890        0.9712
    2       0.5457                      0.9968        0.8223        0.8884
    3       0.3433        0.9968                      0.9504        0.7146
    4       0.0890        0.8223        0.9504                      0.2920
    5       0.9712        0.8884        0.7146        0.2920
```

Appendix C: Statistical Analysis

```
                         The SAS System       14:45 Friday, October 6, 2017 21
                       The GLM Procedure
                    Class Level Information
              Class          Levels    Values
              Samp_Date           4    1 2 3 4
              Station             5    1 2 3 4 5
                  Number of observations    60

                         The SAS System       14:45 Friday, October 6, 2017 22
                       The GLM Procedure
Dependent Variable: Fe   Fe
                                      Sum of
      Source                  DF     Squares     Mean Square    F Value    Pr > F
      Model                   19     1294135.415     68112.390       7.32    <.0001
      Error                   40      372021.171      9300.529
      Corrected Total         59     1666156.586

               R-Square     Coeff Var      Root MSE       Fe Mean
               0.776719      31.74446      96.43925      303.7987


      Source                  DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3     103468.1697      34489.3899       3.71    0.0191
      Station                  4     259089.8658      64772.4664       6.96    0.0002
      Samp_Date*Station       12     931577.3799      77631.4483       8.35    <.0001


      Source                  DF     Type III SS     Mean Square    F Value    Pr > F

      Samp_Date                3     103468.1697      34489.3899       3.71    0.0191
      Station                  4     259089.8658      64772.4664       6.96    0.0002
      Samp_Date*Station       12     931577.3799      77631.4483       8.35    <.0001
                         The SAS System       14:45 Friday, October 6, 2017 23

                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                            LSMEAN
             Samp_Date       Fe LSMEAN      Number
             1              316.786667           1
             2              264.153333           2
             3              268.126667           3
             4              366.128000           4

            Least Squares Means for effect Samp_Date
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: Fe
      i/j           1             2             3             4
         1                   0.4501        0.5179        0.5060
         2       0.4501                    0.9995        0.0299
         3       0.5179        0.9995                    0.0393
         4       0.5060        0.0299        0.0393

                         The SAS System       14:45 Friday, October 6, 2017 24
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                           LSMEAN
              Station       Fe LSMEAN      Number
              1            205.176667           1
              2            306.933333           2
              3            365.616667           3
              4            381.733333           4
              5            259.533333           5

             Least Squares Means for effect Station
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: Fe
 i/j           1             2             3             4             5
    1                   0.0926        0.0019        0.0006        0.6433
    2       0.0926                    0.5745        0.3340        0.7491
    3       0.0019        0.5745                    0.9939        0.0726
    4       0.0006        0.3340        0.9939                    0.0273
    5       0.6433        0.7491        0.0726        0.0273
```

Appendix C: Statistical Analysis

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The GLM Procedure
Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

The SAS System 14:45 Friday, October 6, 2017 26
The GLM Procedure

Dependent Variable: Li Li

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	2.00125525	0.10532922	5.55	<.0001
Error	40	0.75865133	0.01896628		
Corrected Total	59	2.75990658			

R-Square	Coeff Var	Root MSE	Li Mean
0.725117	76.68759	0.137718	0.179583

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	0.18303072	0.06101024	3.22	0.0328
Station	4	0.65760983	0.16440246	8.67	<.0001
Samp_Date*Station	12	1.16061470	0.09671789	5.10	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	0.18303072	0.06101024	3.22	0.0328
Station	4	0.65760983	0.16440246	8.67	<.0001
Samp_Date*Station	12	1.16061470	0.09671789	5.10	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Samp_Date	Li LSMEAN	LSMEAN Number
1	0.18260000	1
2	0.24426667	2
3	0.19920000	3
4	0.09226667	4

Least Squares Means for effect Samp_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Li

i/j	1	2	3	4
1		0.6141	0.9874	0.2901
2	0.6141		0.8068	0.0217
3	0.9874	0.8068		0.1623
4	0.2901	0.0217	0.1623	

The SAS System 14:45 Friday, October 6, 2017 28
The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Station	Li LSMEAN	LSMEAN Number
1	0.37225000	1
2	0.18558333	2
3	0.14141667	3
4	0.14000000	4
5	0.05866667	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Li

i/j	1	2	3	4	5
1		0.0156	0.0017	0.0016	<.0001
2	0.0156		0.9333	0.9258	0.1802
3	0.0017	0.9333		1.0000	0.5862
4	0.0016	0.9258	1.0000		0.6020
5	<.0001	0.1802	0.5862	0.6020	

Appendix C: Statistical Analysis

```
                            The SAS System       14:45 Friday, October 6, 2017 29
                          The GLM Procedure
                       Class Level Information
                 Class          Levels    Values
                 Samp_Date           4    1 2 3 4
                 Station             5    1 2 3 4 5
                     Number of observations    60

                            The SAS System       14:45 Friday, October 6, 2017 30
                          The GLM Procedure
Dependent Variable: V   V
                                     Sum of
      Source                 DF         Squares     Mean Square    F Value    Pr > F
      Model                  19     397.9842309      20.9465385      14.95    <.0001
      Error                  40      56.0448753       1.4011219
      Corrected Total        59     454.0291062

              R-Square     Coeff Var      Root MSE        V Mean
              0.876561      17.35900      1.183690      6.818883

      Source                 DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date               3     173.7653430      57.9217810      41.34    <.0001
      Station                 4      59.3902091      14.8475523      10.60    <.0001
      Samp_Date*Station      12     164.8286788      13.7357232       9.80    <.0001

      Source                 DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date               3     173.7653430      57.9217810      41.34    <.0001
      Station                 4      59.3902091      14.8475523      10.60    <.0001
      Samp_Date*Station      12     164.8286788      13.7357232       9.80    <.0001

                            The SAS System       14:45 Friday, October 6, 2017 31
                          The GLM Procedure
                         Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                             LSMEAN
                Samp_Date        V LSMEAN      Number
                1              4.74113333           1
                2              7.99040000           2
                3              8.92793333           3
                4              5.61606667           4

               Least Squares Means for effect Samp_Date
                 Pr > |t| for H0: LSMean(i)=LSMean(j)
                        Dependent Variable: V
          i/j           1             2             3             4
             1                   <.0001        <.0001        0.1963
             2       <.0001                    0.1495        <.0001
             3       <.0001        0.1495                    <.0001
             4       0.1963        <.0001        <.0001

                            The SAS System       14:45 Friday, October 6, 2017 32
                          The GLM Procedure
                         Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                            LSMEAN
                 Station        V LSMEAN     Number
                 1            6.38116667          1
                 2            5.42833333          2
                 3            6.88808333          3
                 4            8.49591667          4
                 5            6.90091667          5

                Least Squares Means for effect Station
                 Pr > |t| for H0: LSMean(i)=LSMean(j)

                        Dependent Variable: V
   i/j           1             2             3             4             5
      1                   0.2980        0.8309        0.0008        0.8179
      2       0.2980                    0.0336        <.0001        0.0314
      3       0.8309        0.0336                    0.0153        1.0000
      4       0.0008        <.0001        0.0153                    0.0164
      5       0.8179        0.0314        1.0000        0.0164
```

Appendix C: Statistical Analysis

```
                         The SAS System       14:45 Friday, October 6, 2017 33
                       The GLM Procedure
                    Class Level Information
              Class          Levels    Values
              Samp_Date           4    1 2 3 4
              Station             5    1 2 3 4 5

                  Number of observations    60
                         The SAS System       14:45 Friday, October 6, 2017  34
                       The GLM Procedure
Dependent Variable: Cr   Cr
                                     Sum of
      Source                 DF         Squares     Mean Square    F Value    Pr > F
      Model                  19      70.0496897       3.6868258       0.56    0.9091
      Error                  40     261.0727933       6.5268198
      Corrected Total        59     331.1224830

                 R-Square     Coeff Var      Root MSE       Cr Mean
                 0.211552      28.84941      2.554764      8.855517

      Source                 DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date               3      1.22546218      0.40848739       0.06    0.9792
      Station                 4     38.91904307      9.72976077       1.49    0.2232
      Samp_Date*Station      12     29.90518440      2.49209870       0.38    0.9625

      Source                 DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date               3      1.22546218      0.40848739       0.06    0.9792
      Station                 4     38.91904307      9.72976077       1.49    0.2232
      Samp_Date*Station      12     29.90518440      2.49209870       0.38    0.9625

                         The SAS System       14:45 Friday, October 6, 2017 35
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                           LSMEAN
             Samp_Date       Cr LSMEAN      Number
             1              8.93906667           1
             2              8.64406667           2
             3              8.81500000           3
             4              9.02393333           4

            Least Squares Means for effect Samp_Date
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: Cr
      i/j            1             2             3             4
         1                    0.9889        0.9991        0.9997
         2       0.9889                     0.9978        0.9769
         3       0.9991       0.9978                      0.9960
         4       0.9997       0.9769        0.9960

                         The SAS System       14:45 Friday, October 6, 2017 36
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                          LSMEAN
              Station       Cr LSMEAN      Number
              1             7.6811667           1
              2             9.1966667           2
              3            10.1253333           3
              4             8.7786667           4
              5             8.4957500           5

             Least Squares Means for effect Station
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: Cr
   i/j           1             2             3             4             5
      1                   0.5980        0.1526        0.8293        0.9346
      2      0.5980                     0.8988        0.9943        0.9613
      3      0.1526       0.8988                      0.6980        0.5294
      4      0.8293       0.9943        0.6980                      0.9988
      5      0.9346       0.9613        0.5294        0.9988
```

Appendix C: Statistical Analysis

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The GLM Procedure
Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

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The GLM Procedure

Dependent Variable: Mn Mn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	339.2246829	17.8539307	3.47	0.0004
Error	40	205.5418573	5.1385464		
Corrected Total	59	544.7665402			

R-Square	Coeff Var	Root MSE	Mn Mean
0.622697	43.41669	2.266836	5.221117

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	6.7946190	2.2648730	0.44	0.7251
Station	4	77.3255164	19.3313791	3.76	0.0109
Samp_Date*Station	12	255.1045474	21.2587123	4.14	0.0003

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	6.7946190	2.2648730	0.44	0.7251
Station	4	77.3255164	19.3313791	3.76	0.0109
Samp_Date*Station	12	255.1045474	21.2587123	4.14	0.0003

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Samp_Date	Mn LSMEAN	LSMEAN Number
1	5.31753333	1
2	4.66206667	2
3	5.56226667	3
4	5.34260000	4

Least Squares Means for effect Samp_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Mn

i/j	1	2	3	4
1		0.8577	0.9909	1.0000
2	0.8577		0.6991	0.8436
3	0.9909	0.6991		0.9934
4	1.0000	0.8436	0.9934	

The SAS System 14:45 Friday, October 6, 2017 40
The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Station	Mn LSMEAN	LSMEAN Number
1	4.12333333	1
2	6.44950000	2
3	6.15041667	3
4	5.76458333	4
5	3.61775000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Mn

i/j	1	2	3	4	5
1		0.1078	0.2042	0.4027	0.9818
2	0.1078		0.9975	0.9457	0.0305
3	0.2042	0.9975		0.9934	0.0660
4	0.4027	0.9457	0.9934		0.1598
5	0.9818	0.0305	0.0660	0.1598	

Appendix C: Statistical Analysis

```
                    The SAS System       14:45 Friday, October 6, 2017 41
                  The GLM Procedure
               Class Level Information
         Class          Levels    Values
         Samp_Date           4    1 2 3 4
         Station             5    1 2 3 4 5

             Number of observations    60
                    The SAS System       14:45 Friday, October 6, 2017  42
                  The GLM Procedure
Dependent Variable: Ni   Ni
                                       Sum of
      Source                  DF         Squares     Mean Square    F Value    Pr > F
      Model                   19     107.1515447       5.6395550       2.38    0.0103
      Error                   40      94.6152667       2.3653817
      Corrected Total         59     201.7668113

              R-Square     Coeff Var      Root MSE       Ni Mean
              0.531066      23.02135      1.537980      6.680667

      Source                  DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3     39.68317827     13.22772609       5.59    0.0027
      Station                  4      4.11922517      1.02980629       0.44    0.7822
      Samp_Date*Station       12     63.34914123      5.27909510       2.23    0.0287

      Source                  DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3     39.68317827     13.22772609       5.59    0.0027
      Station                  4      4.11922517      1.02980629       0.44    0.7822
      Samp_Date*Station       12     63.34914123      5.27909510       2.23    0.0287

                    The SAS System       14:45 Friday, October 6, 2017 43
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                          LSMEAN
        Samp_Date       Ni LSMEAN      Number
        1              7.76060000           1
        2              7.13193333           2
        3              5.68773333           3
        4              6.14240000           4

         Least Squares Means for effect Samp_Date
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                 Dependent Variable: Ni
    i/j           1              2              3              4
      1                     0.6798         0.0036         0.0309
      2        0.6798                      0.0641         0.3063
      3        0.0036       0.0641                        0.8495
      4        0.0309       0.3063         0.8495

                    The SAS System       14:45 Friday, October 6, 2017 44
                  The GLM Procedure
                 Least Squares Means
       Adjustment for Multiple Comparisons: Tukey
                                         LSMEAN
         Station       Ni LSMEAN      Number
         1            6.17783333           1
         2            6.70866667           2
         3            6.79666667           3
         4            6.93691667           4
         5            6.78325000           5

          Least Squares Means for effect Station
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                 Dependent Variable: Ni
i/j           1              2              3              4              5
  1                     0.9146         0.8602         0.7462         0.8694
  2        0.9146                      0.9999         0.9961         1.0000
  3        0.8602       0.9999                        0.9994         1.0000
  4        0.7462       0.9961         0.9994                        0.9992
  5        0.8694       1.0000         1.0000         0.9992
```

Appendix C: Statistical Analysis

```
                       The SAS System       14:45 Friday, October 6, 2017 45
                     The GLM Procedure
                  Class Level Information
            Class          Levels    Values
            Samp_Date           4    1 2 3 4
            Station             5    1 2 3 4 5
                Number of observations    60

                       The SAS System       14:45 Friday, October 6, 2017 46
                     The GLM Procedure
Dependent Variable: Co   Co
                                   Sum of
      Source                 DF        Squares     Mean Square    F Value    Pr > F
      Model                  19              0               0          .         .
      Error                  40              0               0
      Corrected Total        59              0

                 R-Square     Coeff Var      Root MSE       Co Mean
                 0.000000             .             0             0

      Source                 DF      Type I SS     Mean Square    F Value    Pr > F
      Samp_Date               3              0               0          .         .
      Station                 4              0               0          .         .
      Samp_Date*Station      12              0               0          .         .

      Source                 DF    Type III SS     Mean Square    F Value    Pr > F
      Samp_Date               3              0               0          .         .
      Station                 4              0               0          .         .
      Samp_Date*Station      12              0               0          .         .

                       The SAS System       14:45 Friday, October 6, 2017 47
                     The GLM Procedure
                    Least Squares Means
         Adjustment for Multiple Comparisons: Tukey
                                            LSMEAN
           Samp_Date       Co LSMEAN      Number
           1                       0           1
           2                       0           2
           3                       0           3
           4                       0           4

          Least Squares Means for effect Samp_Date
            Pr > |t| for H0: LSMean(i)=LSMean(j)
                   Dependent Variable: Co
   i/j           1             2             3             4
     1                         .             .             .
     2           .                           .             .
     3           .             .                           .
     4           .             .             .

                       The SAS System       14:45 Friday, October 6, 2017  48
                     The GLM Procedure
                    Least Squares Means
         Adjustment for Multiple Comparisons: Tukey
                                           LSMEAN
            Station       Co LSMEAN      Number
            1                     0           1
            2                     0           2
            3                     0           3
            4                     0           4
            5                     0           5

           Least Squares Means for effect Station
            Pr > |t| for H0: LSMean(i)=LSMean(j)
                   Dependent Variable: Co
i/j           1             2             3             4             5
  1                         .             .             .             .
  2           .                           .             .             .
  3           .             .                           .             .
  4           .             .             .                           .
  5           .             .             .             .
```

Appendix C: Statistical Analysis

```
                    The SAS System        14:45 Friday, October 6, 2017 49
                  The GLM Procedure
               Class Level Information
         Class          Levels    Values
         Samp_Date           4    1 2 3 4
         Station             5    1 2 3 4 5
             Number of observations    60

                    The SAS System        14:45 Friday, October 6, 2017 50
                  The GLM Procedure
Dependent Variable: Zn   Zn
                                        Sum of
      Source                  DF       Squares     Mean Square    F Value    Pr > F
      Model                   19   37785.39555      1988.70503       1.54    0.1225
      Error                   40   51557.69353      1288.94234
      Corrected Total         59   89343.08909

                R-Square     Coeff Var      Root MSE       Zn Mean
                0.422925      30.15175      35.90184      119.0705

      Source                  DF     Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3   22765.70163      7588.56721       5.89    0.0020
      Station                  4    3363.77849       840.94462       0.65    0.6286
      Samp_Date*Station       12   11655.91543       971.32629       0.75    0.6920

      Source                  DF   Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3   22765.70163      7588.56721       5.89    0.0020
      Station                  4    3363.77849       840.94462       0.65    0.6286
      Samp_Date*Station       12   11655.91543       971.32629       0.75    0.6920

                    The SAS System        14:45 Friday, October 6, 2017 51
                  The GLM Procedure
                 Least Squares Means
      Adjustment for Multiple Comparisons: Tukey
                                      LSMEAN
        Samp_Date       Zn LSMEAN      Number
        1              144.717333           1
        2              127.749333           2
        3               92.020667           3
        4              111.794667           4

         Least Squares Means for effect Samp_Date
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                Dependent Variable: Zn
   i/j           1            2            3            4
      1                  0.5718       0.0014       0.0734
      2      0.5718                   0.0450       0.6199
      3      0.0014      0.0450                    0.4421
      4      0.0734      0.6199       0.4421

                    The SAS System        14:45 Friday, October 6, 2017 52
                  The GLM Procedure
                 Least Squares Means
      Adjustment for Multiple Comparisons: Tukey
                                     LSMEAN
         Station       Zn LSMEAN      Number
         1            129.948333           1
         2            108.966667           2
         3            114.973333           3
         4            125.067500           4
         5            116.396667           5

          Least Squares Means for effect Station
           Pr > |t| for H0: LSMean(i)=LSMean(j)
                Dependent Variable: Zn
i/j           1            2            3            4            5
   1                  0.6115       0.8439       0.9972       0.8857
   2      0.6115                   0.9938       0.8062       0.9862
   3      0.8439      0.9938                    0.9578       1.0000
   4      0.9972      0.8062       0.9578                    0.9756
   5      0.8857      0.9862       1.0000       0.9756
```

Appendix C: Statistical Analysis

```
                         The SAS System        14:45 Friday, October 6, 2017 53
                       The GLM Procedure
                    Class Level Information
              Class          Levels    Values
              Samp_Date           4    1 2 3 4
              Station             5    1 2 3 4 5
                  Number of observations    60

                         The SAS System        14:45 Friday, October 6, 2017 54
                       The GLM Procedure
Dependent Variable: As   As
                                    Sum of
      Source                  DF        Squares     Mean Square    F Value    Pr > F
      Model                   19              0               0          .         .
      Error                   40              0               0
      Corrected Total         59              0

                 R-Square     Coeff Var      Root MSE       As Mean
                 0.000000             .             0             0

      Source                  DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3              0               0          .         .
      Station                  4              0               0          .         .
      Samp_Date*Station       12              0               0          .         .

      Source                  DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3              0               0          .         .
      Station                  4              0               0          .         .
      Samp_Date*Station       12              0               0          .         .

                         The SAS System        14:45 Friday, October 6, 2017 55
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                               LSMEAN
             Samp_Date       As LSMEAN       Number
             1                       0            1
             2                       0            2
             3                       0            3
             4                       0            4

            Least Squares Means for effect Samp_Date
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: As
     i/j             1             2             3             4
        1                          .             .             .
        2            .                           .             .
        3            .             .                           .
        4            .             .             .

                         The SAS System        14:45 Friday, October 6, 2017  56
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                              LSMEAN
              Station       As LSMEAN      Number
              1                     0           1
              2                     0           2
              3                     0           3
              4                     0           4
              5                     0           5

             Least Squares Means for effect Station
              Pr > |t| for H0: LSMean(i)=LSMean(j)
                     Dependent Variable: As
i/j             1             2             3             4             5
   1                          .             .             .             .
   2            .                           .             .             .
   3            .             .                           .             .
   4            .             .             .                           .
   5            .             .             .             .
```

Appendix C: Statistical Analysis

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The GLM Procedure

Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

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The GLM Procedure

Dependent Variable: Sr Sr

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	11510.33208	605.80695	0.93	0.5575
Error	40	26159.21268	653.98032		
Corrected Total	59	37669.54476			

R-Square	Coeff Var	Root MSE	Sr Mean
0.305561	271.0621	25.57304	9.434383

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	2362.632903	787.544301	1.20	0.3206
Station	4	2581.385496	645.346374	0.99	0.4258
Samp_Date*Station	12	6566.313678	547.192806	0.84	0.6135

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	2362.632903	787.544301	1.20	0.3206
Station	4	2581.385496	645.346374	0.99	0.4258
Samp_Date*Station	12	6566.313678	547.192806	0.84	0.6135

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The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Samp_Date	Sr LSMEAN	LSMEAN Number
1	19.9339333	1
2	5.1632000	2
3	4.1260000	3
4	8.5144000	4

Least Squares Means for effect Samp_Date

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Sr

i/j	1	2	3	4
1		0.4003	0.3408	0.6162
2	0.4003		0.9995	0.9839
3	0.3408	0.9995		0.9652
4	0.6162	0.9839	0.9652	

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The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Station	Sr LSMEAN	LSMEAN Number
1	3.9870833	1
2	5.2644167	2
3	7.7720000	3
4	7.9441667	4
5	22.2042500	5

Least Squares Means for effect Station

Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Sr

i/j	1	2	3	4	5
1		0.9999	0.9962	0.9954	0.4191
2	0.9999		0.9992	0.9990	0.4922
3	0.9962	0.9992		1.0000	0.6422
4	0.9954	0.9990	1.0000		0.6524
5	0.4191	0.4922	0.6422	0.6524	

Appendix C: Statistical Analysis

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                         The SAS System       14:45 Friday, October 6, 2017 61
                       The GLM Procedure
                    Class Level Information
              Class          Levels    Values
              Samp_Date           4    1 2 3 4
              Station             5    1 2 3 4 5
                  Number of observations    60

                         The SAS System       14:45 Friday, October 6, 2017 62
                       The GLM Procedure
Dependent Variable: Cd   Cd
                                      Sum of
      Source                  DF     Squares     Mean Square    F Value    Pr > F
      Model                   19      0.33744618      0.01776033       1.31    0.2326
      Error                   40      0.54351267      0.01358782
      Corrected Total         59      0.88095885

                R-Square     Coeff Var      Root MSE       Cd Mean
                0.383044      34.03907      0.116567      0.342450

      Source                  DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date                3      0.14016378      0.04672126       3.44    0.0257
      Station                  4      0.06801677      0.01700419       1.25    0.3050
      Samp_Date*Station       12      0.12926563      0.01077214       0.79    0.6550

      Source                  DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date                3      0.14016378      0.04672126       3.44    0.0257
      Station                  4      0.06801677      0.01700419       1.25    0.3050
      Samp_Date*Station       12      0.12926563      0.01077214       0.79    0.6550

                         The SAS System       14:45 Friday, October 6, 2017 63
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                           LSMEAN
             Samp_Date       Cd LSMEAN      Number
             1              0.26420000           1
             2              0.34133333           2
             3              0.37620000           3
             4              0.38806667           4

              Least Squares Means for effect Samp_Date
                Pr > |t| for H0: LSMean(i)=LSMean(j)
                       Dependent Variable: Cd
         i/j           1             2             3             4
            1                   0.2827        0.0560        0.0288
            2        0.2827                   0.8451        0.6928
            3        0.0560       0.8451                    0.9923
            4        0.0288       0.6928        0.9923

                         The SAS System       14:45 Friday, October 6, 2017 64
                       The GLM Procedure
                      Least Squares Means
           Adjustment for Multiple Comparisons: Tukey
                                          LSMEAN
              Station       Cd LSMEAN      Number
              1            0.35191667          1
              2            0.29775000          2
              3            0.34725000          3
              4            0.39700000          4
              5            0.31833333          5

               Least Squares Means for effect Station
                Pr > |t| for H0: LSMean(i)=LSMean(j)
                       Dependent Variable: Cd
  i/j          1             2             3             4             5
     1                   0.7854        1.0000        0.8765        0.9540
     2        0.7854                   0.8352        0.2462        0.9924
     3        1.0000       0.8352                    0.8326        0.9731
     4        0.8765       0.2462        0.8326                    0.4736
     5        0.9540       0.9924        0.9731        0.4736
```

Appendix C: Statistical Analysis

```
                 The SAS System       14:45 Friday, October 6, 2017 65
               The GLM Procedure
            Class Level Information
      Class          Levels    Values
      Samp_Date           4    1 2 3 4
      Station             5    1 2 3 4 5
          Number of observations    60

                 The SAS System       14:45 Friday, October 6, 2017  66
               The GLM Procedure

Dependent Variable: Ba   Ba
                                     Sum of
      Source                 DF         Squares     Mean Square    F Value    Pr > F
      Model                  19     465.6023754      24.5053882       3.44    0.0005
      Error                  40     284.8009553       7.1200239
      Corrected Total        59     750.4033307

                 R-Square     Coeff Var      Root MSE       Ba Mean
                 0.620469      30.76449      2.668337      8.673433

      Source                 DF       Type I SS     Mean Square    F Value    Pr > F
      Samp_Date               3      16.6169202       5.5389734       0.78    0.5132
      Station                 4     246.0103982      61.5025996       8.64    <.0001
      Samp_Date*Station      12     202.9750570      16.9145881       2.38    0.0202

      Source                 DF     Type III SS     Mean Square    F Value    Pr > F
      Samp_Date               3      16.6169202       5.5389734       0.78    0.5132
      Station                 4     246.0103982      61.5025996       8.64    <.0001
      Samp_Date*Station      12     202.9750570      16.9145881       2.38    0.0202

                 The SAS System       14:45 Friday, October 6, 2017 67
               The GLM Procedure
              Least Squares Means
    Adjustment for Multiple Comparisons: Tukey
                                        LSMEAN
     Samp_Date       Ba LSMEAN      Number
     1              9.09306667          1
     2              9.01853333          2
     3              8.80106667          3
     4              7.78106667          4

      Least Squares Means for effect Samp_Date
        Pr > |t| for H0: LSMean(i)=LSMean(j)
              Dependent Variable: Ba
 i/j           1            2            3            4
   1                   0.9998       0.9905       0.5395
   2       0.9998                   0.9960       0.5869
   3       0.9905       0.9960                   0.7232
   4       0.5395       0.5869       0.7232

                 The SAS System       14:45 Friday, October 6, 2017 68
               The GLM Procedure
              Least Squares Means
    Adjustment for Multiple Comparisons: Tukey
                                       LSMEAN
      Station        Ba LSMEAN      Number
      1              6.4333333          1
      2              6.5970000          2
      3             11.9144167          3
      4              9.0004167          4
      5              9.4220000          5

       Least Squares Means for effect Station
        Pr > |t| for H0: LSMean(i)=LSMean(j)
              Dependent Variable: Ba
i/j           1            2            3            4            5
   1                   0.9999       0.0001       0.1487       0.0650
   2       0.9999                   0.0002       0.1983       0.0908
   3       0.0001       0.0002                   0.0759       0.1700
   4       0.1487       0.1983       0.0759                   0.9951
   5       0.0650       0.0908       0.1700       0.9951
```

Appendix C: Statistical Analysis

The SAS System 14:45 Friday, October 6, 2017 69
The GLM Procedure
Class Level Information

Class	Levels	Values
Samp_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 60

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The GLM Procedure

Dependent Variable: Pb Pb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	146.3519783	7.7027357	3.00	0.0017
Error	40	102.6358473	2.5658962		
Corrected Total	59	248.9878257			

R-Square	Coeff Var	Root MSE	Pb Mean
0.587788	178.5478	1.601841	0.897150

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Samp_Date	3	13.8464565	4.6154855	1.80	0.1629
Station	4	14.6184996	3.6546249	1.42	0.2436
Samp_Date*Station	12	117.8870223	9.8239185	3.83	0.0007

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Samp_Date	3	13.8464565	4.6154855	1.80	0.1629
Station	4	14.6184996	3.6546249	1.42	0.2436
Samp_Date*Station	12	117.8870223	9.8239185	3.83	0.0007

The SAS System 14:45 Friday, October 6, 2017 71
The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Samp_Date	Pb LSMEAN	LSMEAN Number
1	0.22626667	1
2	0.84506667	2
3	1.58186667	3
4	0.93540000	4

Least Squares Means for effect Samp_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Pb

i/j	1	2	3	4
1		0.7167	0.1110	0.6228
2	0.7167		0.5934	0.9987
3	0.1110	0.5934		0.6884
4	0.6228	0.9987	0.6884	

The SAS System 14:45 Friday, October 6, 2017 72
The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

Station	Pb LSMEAN	LSMEAN Number
1	0.89975000	1
2	1.00758333	2
3	1.07275000	3
4	0.00000000	4
5	1.50566667	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Pb

i/j	1	2	3	4	5
1		0.9998	0.9989	0.6462	0.8849
2	0.9998		1.0000	0.5429	0.9400
3	0.9989	1.0000		0.4813	0.9633
4	0.6462	0.5429	0.4813		0.1653
5	0.8849	0.9400	0.9633	0.1653	

Appendix C: Statistical Analysis

NOTE: I COMPUTED THE MEANS & STANDARD ERRORS. YOU CAN USE THEM FOR YOUR REPORTING BUT USE THE TUKEY TEST STATISTICAL DIFFERENCES TO COMPARE THESE MEANS

The SAS System 18:34 Sunday, October 8, 2017 1

Sampling_Date=1

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	10	140.9667542	10.7478976	87.6500000	186.8588443
Al	Al	10	1303.01	191.9381384	493.0000000	2395.00
Ca	Ca	10	10108.80	1357.43	3727.00	19110.00
Na	Na	10	814.6500000	70.0205958	592.9000000	1123.00
Mg	Mg	10	2093.61	223.7289603	763.1000000	2855.00
Fe	Fe	10	1330.45	175.8242274	540.2000000	2311.00
Li	Li	10	0.8346000	0.1315472	0.2440000	1.5580000
V	V	10	8.5670000	0.4789819	6.5680000	10.4600000
Cr	Cr	10	12.8640000	0.5231214	10.7200000	15.6500000
Mn	Mn	10	17.4878000	2.2752330	6.9160000	29.3000000
Ni	Ni	10	10.7868000	0.6527726	7.8520000	15.0100000
Co	Co	10	0.0764000	0.0519913	0	0.4520000
Zn	Zn	10	148.9410000	26.5477089	52.5800000	279.0000000
As	As	10	0	0	0	0
Sr	Sr	10	29.2990000	1.6282161	19.6000000	36.2700000
Cd	Cd	10	0.2418000	0.0446624	0	0.5290000
Ba	Ba	10	24.7770000	1.8981881	14.1900000	30.5400000
Pb	Pb	10	0.6581000	0.4484166	0	4.2470000

Sampling_Date=2

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	9	153.6347835	13.6538909	106.6215558	213.9679639
Al	Al	9	1259.47	178.1916634	597.6000000	2124.00
Ca	Ca	9	9841.56	1579.14	4857.00	19840.00
Na	Na	9	562.9111111	47.6340811	379.2000000	839.9000000
Mg	Mg	9	1858.47	238.6053617	857.9000000	3027.00
Fe	Fe	9	1394.10	156.2810662	667.6000000	1989.00
Li	Li	9	1.1930000	0.3045770	0.2940000	2.9710000
V	V	9	12.8911111	0.3935749	10.5300000	13.9400000
Cr	Cr	9	13.6971111	0.7752978	9.1540000	17.4900000
Mn	Mn	9	15.7866667	1.8714766	7.2390000	21.1200000
Ni	Ni	9	11.9588889	0.3711485	10.0700000	13.6000000
Co	Co	9	0.1557778	0.1007623	0	0.9100000
Zn	Zn	9	132.9433333	26.1436501	70.6900000	323.2000000
As	As	9	0	0	0	0
Sr	Sr	9	29.0155556	3.8312313	14.3000000	52.1800000
Cd	Cd	9	0.2544444	0.0394416	0.0990000	0.4830000
Ba	Ba	9	34.3788889	4.2761520	17.5400000	56.9400000
Pb	Pb	9	2.7748889	0.8847971	0	7.3410000

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Sampling_Date=3

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	10	190.0108368	11.9337354	115.4979285	239.8255055
Al	Al	10	1248.29	208.2876214	531.7000000	2465.00
Ca	Ca	10	11544.50	1660.49	2777.00	19060.00
Na	Na	10	666.6000000	102.4323929	242.3000000	1213.00
Mg	Mg	10	2302.45	296.2850344	627.9000000	3436.00
Fe	Fe	10	1515.58	178.4527835	912.6000000	2499.00
Li	Li	10	1.1006000	0.1701836	0.2020000	1.9500000
V	V	10	13.9810000	0.8444281	10.7700000	18.6100000
Cr	Cr	10	13.6070000	0.8245484	10.3800000	17.4100000
Mn	Mn	10	17.3597000	1.9661932	8.3500000	26.4600000
Ni	Ni	10	11.0038000	0.7838067	8.4010000	15.8300000
Co	Co	10	0.0537000	0.0428123	0	0.4260000
Zn	Zn	10	124.5420000	15.7734028	58.7000000	204.2000000
As	As	10	0	0	0	0
Sr	Sr	10	34.5945000	4.9800596	9.8950000	56.0700000

Cd	Cd	10	0.4128000	0.0246630	0.2780000	0.4950000
Ba	Ba	10	43.2930000	2.3764792	35.5500000	57.7400000
Pb	Pb	10	2.5442000	0.8788419	0	6.8460000

-- Sampling_Date=4 --

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	10	145.2970000	16.3851203	77.9800000	214.0500000
Al	Al	10	1433.71	389.5061926	311.6000000	3660.00
Ca	Ca	10	9340.00	2043.45	3791.00	20480.00
Na	Na	10	758.9000000	125.0347463	120.9000000	1252.00
Mg	Mg	10	1847.94	472.2598450	378.2000000	4410.00
Fe	Fe	10	1568.23	388.1998586	499.0000000	3752.00
Li	Li	10	1.0053000	0.3247419	0.0320000	2.6950000
V	V	10	10.1890000	1.1608898	5.6490000	14.7100000
Cr	Cr	10	12.0682000	1.2006303	8.1840000	19.2800000
Mn	Mn	10	15.2171000	3.1697469	4.9830000	32.2400000
Ni	Ni	10	10.0195000	1.2335396	4.9850000	15.5200000
Co	Co	10	0.3157000	0.2011054	0	1.5810000
Zn	Zn	10	123.1600000	16.4520851	59.5100000	237.5000000
As	As	10	0	0	0	0
Sr	Sr	10	31.4608000	8.2691083	6.4080000	73.9300000
Cd	Cd	10	0.3508000	0.0364989	0.1250000	0.5410000
Ba	Ba	10	30.2340000	6.3463059	14.6600000	65.3100000
Pb	Pb	10	0.6315000	0.3583771	0	3.1560000

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-- Station=1 --

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	163.5506531	3.8776275	159.6730256	167.4282806
Al	Al	2	1125.50	7.5000000	1118.00	1133.00
Ca	Ca	2	11160.00	1070.00	10090.00	12230.00
Na	Na	2	632.3000000	10.0000000	622.3000000	642.3000000
Mg	Mg	2	2505.00	20.0000000	2485.00	2525.00
Fe	Fe	2	1235.50	21.5000000	1214.00	1257.00
Li	Li	2	0.7935000	0.0105000	0.7830000	0.8040000
V	V	2	9.9305000	0.0665000	9.8640000	9.9970000
Cr	Cr	2	12.4500000	0.1300000	12.3200000	12.5800000
Mn	Mn	2	20.0650000	0.0950000	19.9700000	20.1600000
Ni	Ni	2	10.6300000	0.1300000	10.5000000	10.7600000
Co	Co	2	0	0	0	0
Zn	Zn	2	225.4000000	53.6000000	171.8000000	279.0000000
As	As	2	0	0	0	0
Sr	Sr	2	33.1150000	0.2550000	32.8600000	33.3700000
Cd	Cd	2	0.2035000	0.0275000	0.1760000	0.2310000
Ba	Ba	2	26.0100000	0.8200000	25.1900000	26.8300000
Pb	Pb	2	3.1635000	1.0835000	2.0800000	4.2470000

-- Station=2 --

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	158.4813993	5.2004007	153.2809986	163.6818000
Al	Al	2	2254.00	141.0000000	2113.00	2395.00
Ca	Ca	2	10565.00	1085.00	9480.00	11650.00
Na	Na	2	1071.00	52.0000000	1019.00	1123.00
Mg	Mg	2	2427.50	165.5000000	2262.00	2593.00
Fe	Fe	2	2194.00	117.0000000	2077.00	2311.00
Li	Li	2	1.4605000	0.0975000	1.3630000	1.5580000
V	V	2	9.0335000	0.5305000	8.5030000	9.5640000
Cr	Cr	2	14.8900000	0.7600000	14.1300000	15.6500000
Mn	Mn	2	27.1750000	2.1250000	25.0500000	29.3000000
Ni	Ni	2	14.0150000	0.9950000	13.0200000	15.0100000
Co	Co	2	0.3820000	0.0700000	0.3120000	0.4520000
Zn	Zn	2	179.0000000	59.2000000	119.8000000	238.2000000
As	As	2	0	0	0	0
Sr	Sr	2	30.1000000	1.4500000	28.6500000	31.5500000
Cd	Cd	2	0.1735000	0.0105000	0.1630000	0.1840000
Ba	Ba	2	29.3700000	1.1200000	28.2500000	30.4900000

Appendix C: Statistical Analysis

Pb	Pb	2	0.1270000	0.1270000	0	0.2540000

Station=3

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	119.5699325	8.1441752	111.4257573	127.7141077
Al	Al	2	1038.50	10.5000000	1028.00	1049.00
Ca	Ca	2	9048.00	281.0000000	8767.00	9329.00
Na	Na	2	846.2500000	210.7500000	635.5000000	1057.00
Mg	Mg	2	1912.50	71.5000000	1841.00	1984.00
Fe	Fe	2	1120.00	2.0000000	1118.00	1122.00
Li	Li	2	0.6430000	0.0270000	0.6160000	0.6700000
V	V	2	7.0540000	0.0620000	6.9920000	7.1160000
Cr	Cr	2	13.8750000	1.5050000	12.3700000	15.3800000
Mn	Mn	2	13.6450000	0.3950000	13.2500000	14.0400000
Ni	Ni	2	9.9080000	0.0490000	9.8590000	9.9570000
Co	Co	2	0	0	0	0
Zn	Zn	2	74.2650000	7.5850000	66.6800000	81.8500000
As	As	2	0	0	0	0
Sr	Sr	2	28.2900000	0.6200000	27.6700000	28.9100000
Cd	Cd	2	0.2370000	0.0660000	0.1710000	0.3030000
Ba	Ba	2	23.3450000	1.0650000	22.2800000	24.4100000
Pb	Pb	2	0	0	0	0

Station=4

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	173.1228166	13.7360277	159.3867889	186.8588443
Al	Al	2	1548.00	17.0000000	1531.00	1565.00
Ca	Ca	2	15610.00	3500.00	12110.00	19110.00
Na	Na	2	701.7500000	90.4500000	611.3000000	792.2000000
Mg	Mg	2	2738.50	116.5000000	2622.00	2855.00
Fe	Fe	2	1509.00	22.0000000	1487.00	1531.00
Li	Li	2	0.9925000	0.0895000	0.9030000	1.0820000
V	V	2	10.0540000	0.4060000	9.6480000	10.4600000
Cr	Cr	2	12.0250000	0.3750000	11.6500000	12.4000000
Mn	Mn	2	19.4850000	0.6750000	18.8100000	20.1600000
Ni	Ni	2	11.1750000	0.1050000	11.0700000	11.2800000
Co	Co	2	0	0	0	0
Zn	Zn	2	187.5000000	76.4000000	111.1000000	263.9000000
As	As	2	0	0	0	0
Sr	Sr	2	34.1200000	2.1500000	31.9700000	36.2700000
Cd	Cd	2	0.2645000	0.2645000	0	0.5290000
Ba	Ba	2	30.4700000	0.0700000	30.4000000	30.5400000
Pb	Pb	2	0	0	0	0

Sampling_Date=1 Station=1

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	163.5506531	3.8776275	159.6730256	167.4282806
Al	Al	2	1125.50	7.5000000	1118.00	1133.00
Ca	Ca	2	11160.00	1070.00	10090.00	12230.00
Na	Na	2	632.3000000	10.0000000	622.3000000	642.3000000
Mg	Mg	2	2505.00	20.0000000	2485.00	2525.00
Fe	Fe	2	1235.50	21.5000000	1214.00	1257.00
Li	Li	2	0.7935000	0.0105000	0.7830000	0.8040000
V	V	2	9.9305000	0.0665000	9.8640000	9.9970000
Cr	Cr	2	12.4500000	0.1300000	12.3200000	12.5800000
Mn	Mn	2	20.0650000	0.0950000	19.9700000	20.1600000
Ni	Ni	2	10.6300000	0.1300000	10.5000000	10.7600000
Co	Co	2	0	0	0	0
Zn	Zn	2	225.4000000	53.6000000	171.8000000	279.0000000
As	As	2	0	0	0	0
Sr	Sr	2	33.1150000	0.2550000	32.8600000	33.3700000
Cd	Cd	2	0.2035000	0.0275000	0.1760000	0.2310000
Ba	Ba	2	26.0100000	0.8200000	25.1900000	26.8300000

Pb	Pb	2	3.1635000	1.0835000	2.0800000	4.2470000

------------------------------------ Sampling_Date=1 Station=2 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	158.4813993	5.2004007	153.2809986	163.6818000
Al	Al	2	2254.00	141.0000000	2113.00	2395.00
Ca	Ca	2	10565.00	1085.00	9480.00	11650.00
Na	Na	2	1071.00	52.0000000	1019.00	1123.00
Mg	Mg	2	2427.50	165.5000000	2262.00	2593.00
Fe	Fe	2	2194.00	117.0000000	2077.00	2311.00
Li	Li	2	1.4605000	0.0975000	1.3630000	1.5580000
V	V	2	9.0335000	0.5305000	8.5030000	9.5640000
Cr	Cr	2	14.8900000	0.7600000	14.1300000	15.6500000
Mn	Mn	2	27.1750000	2.1250000	25.0500000	29.3000000
Ni	Ni	2	14.0150000	0.9950000	13.0200000	15.0100000
Co	Co	2	0.3820000	0.0700000	0.3120000	0.4520000
Zn	Zn	2	179.0000000	59.2000000	119.8000000	238.2000000
As	As	2	0	0	0	0
Sr	Sr	2	30.1000000	1.4500000	28.6500000	31.5500000
Cd	Cd	2	0.1735000	0.0105000	0.1630000	0.1840000
Ba	Ba	2	29.3700000	1.1200000	28.2500000	30.4900000
Pb	Pb	2	0.1270000	0.1270000	0	0.2540000

------------------------------------ Sampling_Date=1 Station=3 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	119.5699325	8.1441752	111.4257573	127.7141077
Al	Al	2	1038.50	10.5000000	1028.00	1049.00
Ca	Ca	2	9048.00	281.0000000	8767.00	9329.00
Na	Na	2	846.2500000	210.7500000	635.5000000	1057.00
Mg	Mg	2	1912.50	71.5000000	1841.00	1984.00
Fe	Fe	2	1120.00	2.0000000	1118.00	1122.00
Li	Li	2	0.6430000	0.0270000	0.6160000	0.6700000
V	V	2	7.0540000	0.0620000	6.9920000	7.1160000
Cr	Cr	2	13.8750000	1.5050000	12.3700000	15.3800000
Mn	Mn	2	13.6450000	0.3950000	13.2500000	14.0400000
Ni	Ni	2	9.9080000	0.0490000	9.8590000	9.9570000
Co	Co	2	0	0	0	0
Zn	Zn	2	74.2650000	7.5850000	66.6800000	81.8500000
As	As	2	0	0	0	0
Sr	Sr	2	28.2900000	0.6200000	27.6700000	28.9100000
Cd	Cd	2	0.2370000	0.0660000	0.1710000	0.3030000
Ba	Ba	2	23.3450000	1.0650000	22.2800000	24.4100000
Pb	Pb	2	0	0	0	0

------------------------------------ Sampling_Date=1 Station=4 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	173.1228166	13.7360277	159.3867889	186.8588443
Al	Al	2	1548.00	17.0000000	1531.00	1565.00
Ca	Ca	2	15610.00	3500.00	12110.00	19110.00
Na	Na	2	701.7500000	90.4500000	611.3000000	792.2000000
Mg	Mg	2	2738.50	116.5000000	2622.00	2855.00
Fe	Fe	2	1509.00	22.0000000	1487.00	1531.00
Li	Li	2	0.9925000	0.0895000	0.9030000	1.0820000
V	V	2	10.0540000	0.4060000	9.6480000	10.4600000
Cr	Cr	2	12.0250000	0.3750000	11.6500000	12.4000000
Mn	Mn	2	19.4850000	0.6750000	18.8100000	20.1600000
Ni	Ni	2	11.1750000	0.1050000	11.0700000	11.2800000
Co	Co	2	0	0	0	0
Zn	Zn	2	187.5000000	76.4000000	111.1000000	263.9000000
As	As	2	0	0	0	0
Sr	Sr	2	34.1200000	2.1500000	31.9700000	36.2700000
Cd	Cd	2	0.2645000	0.2645000	0	0.5290000
Ba	Ba	2	30.4700000	0.0700000	30.4000000	30.5400000

Appendix C: Statistical Analysis

Pb	Pb	2	0	0	0	0

------------------------------------ Sampling_Date=1 Station=5 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	90.1089693	2.4589693	87.6500000	92.5679386
Al	Al	2	549.0500000	56.0500000	493.0000000	605.1000000
Ca	Ca	2	4161.00	434.0000000	3727.00	4595.00
Na	Na	2	821.9500000	229.0500000	592.9000000	1051.00
Mg	Mg	2	884.5500000	121.4500000	763.1000000	1006.00
Fe	Fe	2	593.7500000	53.5500000	540.2000000	647.3000000
Li	Li	2	0.2835000	0.0395000	0.2440000	0.3230000
V	V	2	6.7630000	0.1950000	6.5680000	6.9580000
Cr	Cr	2	11.0800000	0.3600000	10.7200000	11.4400000
Mn	Mn	2	7.0690000	0.1530000	6.9160000	7.2220000
Ni	Ni	2	8.2060000	0.3540000	7.8520000	8.5600000
Co	Co	2	0	0	0	0
Zn	Zn	2	78.5400000	25.9600000	52.5800000	104.5000000
As	As	2	0	0	0	0
Sr	Sr	2	20.8700000	1.2700000	19.6000000	22.1400000
Cd	Cd	2	0.3305000	0.0065000	0.3240000	0.3370000
Ba	Ba	2	14.6900000	0.5000000	14.1900000	15.1900000
Pb	Pb	2	0	0	0	0

------------------------------------ Sampling_Date=2 Station=1 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	191.9873670	3.5726478	188.4147192	195.5600148
Al	Al	2	2070.50	53.5000000	2017.00	2124.00
Ca	Ca	2	14688.50	5151.50	9537.00	19840.00
Na	Na	2	784.8000000	55.1000000	729.7000000	839.9000000
Mg	Mg	2	2432.50	227.5000000	2205.00	2660.00
Fe	Fe	2	1960.50	28.5000000	1932.00	1989.00
Li	Li	2	2.7050000	0.2660000	2.4390000	2.9710000
V	V	2	13.0450000	0.0650000	12.9800000	13.1100000
Cr	Cr	2	15.5600000	1.9300000	13.6300000	17.4900000
Mn	Mn	2	20.8200000	0.3000000	20.5200000	21.1200000
Ni	Ni	2	12.1300000	1.4700000	10.6600000	13.6000000
Co	Co	2	0.2460000	0.0120000	0.2340000	0.2580000
Zn	Zn	2	220.4000000	102.8000000	117.6000000	323.2000000
As	As	2	0	0	0	0
Sr	Sr	2	34.5150000	2.3650000	32.1500000	36.8800000
Cd	Cd	2	0.2620000	0.0120000	0.2500000	0.2740000
Ba	Ba	2	35.1650000	2.2050000	32.9600000	37.3700000
Pb	Pb	2	2.1275000	1.5785000	0.5490000	3.7060000

------------------------------------ Sampling_Date=2 Station=2 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	117.3200295	5.5700295	111.7500000	122.8900590
Al	Al	2	1268.50	19.5000000	1249.00	1288.00
Ca	Ca	2	8014.50	323.5000000	7691.00	8338.00
Na	Na	2	566.2500000	7.2500000	559.0000000	573.5000000
Mg	Mg	2	1751.50	18.5000000	1733.00	1770.00
Fe	Fe	2	1482.50	4.5000000	1478.00	1487.00
Li	Li	2	1.0670000	0.0240000	1.0430000	1.0910000
V	V	2	13.7700000	0.0600000	13.7100000	13.8300000
Cr	Cr	2	14.0550000	0.8550000	13.2000000	14.9100000
Mn	Mn	2	20.3150000	0.0250000	20.2900000	20.3400000
Ni	Ni	2	12.0950000	0.3850000	11.7100000	12.4800000
Co	Co	2	0	0	0	0
Zn	Zn	2	82.9400000	12.2500000	70.6900000	95.1900000
As	As	2	0	0	0	0
Sr	Sr	2	24.7100000	0.3500000	24.3600000	25.0600000

Cd	Cd	2	0.1445000	0.0455000	0.0990000	0.1900000
Ba	Ba	2	29.8800000	0.4200000	29.4600000	30.3000000
Pb	Pb	2	6.3000000	1.0410000	5.2590000	7.3410000

------------------------------------ Sampling_Date=2 Station=3 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	165.0029303	4.2750001	160.7279302	169.2779305
Al	Al	2	1051.50	31.5000000	1020.00	1083.00
Ca	Ca	2	8968.50	461.5000000	8507.00	9430.00
Na	Na	2	462.1000000	17.5000000	444.6000000	479.6000000
Mg	Mg	2	1791.50	7.5000000	1784.00	1799.00
Fe	Fe	2	1300.00	39.0000000	1261.00	1339.00
Li	Li	2	0.8255000	0.1665000	0.6590000	0.9920000
V	V	2	11.9900000	0.2700000	11.7200000	12.2600000
Cr	Cr	2	14.4250000	1.4050000	13.0200000	15.8300000
Mn	Mn	2	12.9250000	0.2650000	12.6600000	13.1900000
Ni	Ni	2	12.2550000	0.7650000	11.4900000	13.0200000
Co	Co	2	0.4550000	0.4550000	0	0.9100000
Zn	Zn	2	109.8700000	37.3300000	72.5400000	147.2000000
As	As	2	0	0	0	0
Sr	Sr	2	30.4950000	0.0750000	30.4200000	30.5700000
Cd	Cd	2	0.4375000	0.0455000	0.3920000	0.4830000
Ba	Ba	2	43.4650000	4.2350000	39.2300000	47.7000000
Pb	Pb	2	1.2405000	1.2405000	0	2.4810000

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------------------------------------ Sampling_Date=2 Station=4 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	110.0622168	3.4406610	106.6215558	113.5028779
Al	Al	2	601.1000000	3.5000000	597.6000000	604.6000000
Ca	Ca	2	5135.50	278.5000000	4857.00	5414.00
Na	Na	2	439.4000000	60.2000000	379.2000000	499.6000000
Mg	Mg	2	874.1000000	16.2000000	857.9000000	890.3000000
Fe	Fe	2	688.9500000	21.3500000	667.6000000	710.3000000
Li	Li	2	0.3215000	0.0275000	0.2940000	0.3490000
V	V	2	13.9400000	0	13.9400000	13.9400000
Cr	Cr	2	10.8120000	1.6580000	9.1540000	12.4700000
Mn	Mn	2	7.5850000	0.3460000	7.2390000	7.9310000
Ni	Ni	2	11.1000000	1.0300000	10.0700000	12.1300000
Co	Co	2	0	0	0	0
Zn	Zn	2	117.5350000	39.6650000	77.8700000	157.2000000
As	As	2	0	0	0	0
Sr	Sr	2	14.7600000	0.4600000	14.3000000	15.2200000
Cd	Cd	2	0.2220000	0.0190000	0.2030000	0.2410000
Ba	Ba	2	17.7250000	0.1850000	17.5400000	17.9100000
Pb	Pb	2	0.3890000	0.0530000	0.3360000	0.4420000

------------------------------------ Sampling_Date=2 Station=5 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	1	213.9679639	.	213.9679639	213.9679639
Al	Al	1	1352.00	.	1352.00	1352.00
Ca	Ca	1	14960.00	.	14960.00	14960.00
Na	Na	1	561.1000000	.	561.1000000	561.1000000
Mg	Mg	1	3027.00	.	3027.00	3027.00
Fe	Fe	1	1683.00	.	1683.00	1683.00
Li	Li	1	0.8990000	.	0.8990000	0.8990000
V	V	1	10.5300000	.	10.5300000	10.5300000
Cr	Cr	1	13.5700000	.	13.5700000	13.5700000
Mn	Mn	1	18.7900000	.	18.7900000	18.7900000
Ni	Ni	1	12.4700000	.	12.4700000	12.4700000
Co	Co	1	0	.	0	0
Zn	Zn	1	135.0000000	.	135.0000000	135.0000000
As	As	1	0	.	0	0
Sr	Sr	1	52.1800000	.	52.1800000	52.1800000

Variable	Label	N	Mean	Std Error	Minimum	Maximum
Cd	Cd	1	0.1580000	.	0.1580000	0.1580000
Ba	Ba	1	56.9400000	.	56.9400000	56.9400000
Pb	Pb	1	4.8600000	.	4.8600000	4.8600000

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------------------------------------ Sampling_Date=3 Station=1 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	195.3131784	1.6131784	193.7000000	196.9263568
Al	Al	2	739.4500000	9.8500000	729.6000000	749.3000000
Ca	Ca	2	12890.00	1760.00	11130.00	14650.00
Na	Na	2	461.1500000	12.5500000	448.6000000	473.7000000
Mg	Mg	2	2187.00	1.0000000	2186.00	2188.00
Fe	Fe	2	1009.60	11.4000000	998.2000000	1021.00
Li	Li	2	1.2555000	0.0015000	1.2540000	1.2570000
V	V	2	12.0350000	0.0750000	11.9600000	12.1100000
Cr	Cr	2	11.1400000	0.2000000	10.9400000	11.3400000
Mn	Mn	2	12.3400000	0.5000000	11.8400000	12.8400000
Ni	Ni	2	8.6785000	0.2775000	8.4010000	8.9560000
Co	Co	2	0	0	0	0
Zn	Zn	2	149.1350000	55.0650000	94.0700000	204.2000000
As	As	2	0	0	0	0
Sr	Sr	2	25.5050000	0.2350000	25.2700000	25.7400000
Cd	Cd	2	0.3675000	0.0665000	0.3010000	0.4340000
Ba	Ba	2	39.0550000	1.0150000	38.0400000	40.0700000
Pb	Pb	2	4.6275000	0.4985000	4.1290000	5.1260000

------------------------------------ Sampling_Date=3 Station=2 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	195.9670936	0.3807126	195.5863811	196.3478062
Al	Al	2	1252.50	31.5000000	1221.00	1284.00
Ca	Ca	2	18500.00	560.0000000	17940.00	19060.00
Na	Na	2	918.8500000	6.9500000	911.9000000	925.8000000
Mg	Mg	2	3391.50	44.5000000	3347.00	3436.00
Fe	Fe	2	1390.00	33.0000000	1357.00	1423.00
Li	Li	2	1.1165000	0.1385000	0.9780000	1.2550000
V	V	2	11.1900000	0.4200000	10.7700000	11.6100000
Cr	Cr	2	14.8700000	0.9600000	13.9100000	15.8300000
Mn	Mn	2	20.4050000	0.4250000	19.9800000	20.8300000
Ni	Ni	2	9.3430000	0.0140000	9.3290000	9.3570000
Co	Co	2	0	0	0	0
Zn	Zn	2	149.4500000	18.2500000	131.2000000	167.7000000
As	As	2	0	0	0	0
Sr	Sr	2	46.5700000	0.3900000	46.1800000	46.9600000
Cd	Cd	2	0.3545000	0.0765000	0.2780000	0.4310000
Ba	Ba	2	36.4550000	0.9050000	35.5500000	37.3600000
Pb	Pb	2	0	0	0	0

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------------------------------------ Sampling_Date=3 Station=3 ------------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	239.5947958	0.2307097	239.3640862	239.8255055
Al	Al	2	1282.50	42.5000000	1240.00	1325.00
Ca	Ca	2	12270.00	1660.00	10610.00	13930.00
Na	Na	2	569.3500000	49.6500000	519.7000000	619.0000000
Mg	Mg	2	2467.00	30.0000000	2437.00	2497.00
Fe	Fe	2	1718.00	19.0000000	1699.00	1737.00
Li	Li	2	1.0395000	0.0265000	1.0130000	1.0660000
V	V	2	18.2650000	0.3450000	17.9200000	18.6100000
Cr	Cr	2	14.8250000	0.8850000	13.9400000	15.7100000
Mn	Mn	2	19.5450000	1.0750000	18.4700000	20.6200000
Ni	Ni	2	13.9350000	1.8950000	12.0400000	15.8300000
Co	Co	2	0	0	0	0
Zn	Zn	2	133.2650000	42.0350000	91.2300000	175.3000000

As	As	2	0	0	0	0
Sr	Sr	2	42.9000000	7.6800000	35.2200000	50.5800000
Cd	Cd	2	0.4700000	0.0250000	0.4450000	0.4950000
Ba	Ba	2	56.2700000	1.4700000	54.8000000	57.7400000
Pb	Pb	2	6.0815000	0.7645000	5.3170000	6.8460000

----------------------------------- Sampling_Date=3 Station=4 -----------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	189.9572381	0.1527619	189.8044761	190.1100000
Al	Al	2	2368.00	97.0000000	2271.00	2465.00
Ca	Ca	2	10389.00	1761.00	8628.00	12150.00
Na	Na	2	1103.90	109.1000000	994.8000000	1213.00
Mg	Mg	2	2747.00	100.0000000	2647.00	2847.00
Fe	Fe	2	2441.50	57.5000000	2384.00	2499.00
Li	Li	2	1.8305000	0.1195000	1.7110000	1.9500000
V	V	2	14.6450000	0.0550000	14.5900000	14.7000000
Cr	Cr	2	16.6950000	0.7150000	15.9800000	17.4100000
Mn	Mn	2	25.3550000	1.1050000	24.2500000	26.4600000
Ni	Ni	2	13.2800000	0.7400000	12.5400000	14.0200000
Co	Co	2	0.2685000	0.1575000	0.1110000	0.4260000
Zn	Zn	2	109.4000000	50.7000000	58.7000000	160.1000000
As	As	2	0	0	0	0
Sr	Sr	2	46.3400000	9.7300000	36.6100000	56.0700000
Cd	Cd	2	0.4235000	0.0655000	0.3580000	0.4890000
Ba	Ba	2	41.5300000	0.8200000	40.7100000	42.3500000
Pb	Pb	2	0.0260000	0.0260000	0	0.0520000

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----------------------------------- Sampling_Date=3 Station=5 -----------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	129.2218781	13.7239496	115.4979285	142.9458277
Al	Al	2	599.0000000	67.3000000	531.7000000	666.3000000
Ca	Ca	2	3673.50	896.5000000	2777.00	4570.00
Na	Na	2	279.7500000	37.4500000	242.3000000	317.2000000
Mg	Mg	2	719.7500000	91.8500000	627.9000000	811.6000000
Fe	Fe	2	1018.80	106.2000000	912.6000000	1125.00
Li	Li	2	0.2610000	0.0590000	0.2020000	0.3200000
V	V	2	13.7700000	1.1700000	12.6000000	14.9400000
Cr	Cr	2	10.5050000	0.1250000	10.3800000	10.6300000
Mn	Mn	2	9.1535000	0.8035000	8.3500000	9.9570000
Ni	Ni	2	9.7825000	0.0135000	9.7690000	9.7960000
Co	Co	2	0	0	0	0
Zn	Zn	2	81.4600000	10.3300000	71.1300000	91.7900000
As	As	2	0	0	0	0
Sr	Sr	2	11.6575000	1.7625000	9.8950000	13.4200000
Cd	Cd	2	0.4485000	0.0455000	0.4030000	0.4940000
Ba	Ba	2	43.1550000	3.6350000	39.5200000	46.7900000
Pb	Pb	2	1.9860000	1.9860000	0	3.9720000

----------------------------------- Sampling_Date=4 Station=1 -----------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	117.1350000	6.2750000	110.8600000	123.4100000
Al	Al	2	704.6000000	12.2000000	692.4000000	716.8000000
Ca	Ca	2	4446.50	34.5000000	4412.00	4481.00
Na	Na	2	1232.00	20.0000000	1212.00	1252.00
Mg	Mg	2	1023.50	1.5000000	1022.00	1025.00
Fe	Fe	2	760.0500000	0.5500000	759.5000000	760.6000000
Li	Li	2	0.3910000	0.0270000	0.3640000	0.4180000
V	V	2	7.0495000	0.0425000	7.0070000	7.0920000
Cr	Cr	2	10.2155000	0.6545000	9.5610000	10.8700000
Mn	Mn	2	7.2270000	0.3310000	6.8960000	7.5580000
Ni	Ni	2	5.8770000	0.1190000	5.7580000	5.9960000
Co	Co	2	0	0	0	0
Zn	Zn	2	85.5850000	15.0150000	70.5700000	100.6000000

As	As	2	0	0	0	0
Sr	Sr	2	14.0000000	0.1000000	13.9000000	14.1000000
Cd	Cd	2	0.2275000	0.1025000	0.1250000	0.3300000
Ba	Ba	2	15.8300000	0.1600000	15.6700000	15.9900000
Pb	Pb	2	0	0	0	0

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----------------------------------- Sampling_Date=4 Station=2 -----------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	80.5100000	2.5300000	77.9800000	83.0400000
Al	Al	2	365.1500000	53.5500000	311.6000000	418.7000000
Ca	Ca	2	4030.00	239.0000000	3791.00	4269.00
Na	Na	2	147.6000000	26.7000000	120.9000000	174.3000000
Mg	Mg	2	470.7500000	92.5500000	378.2000000	563.3000000
Fe	Fe	2	566.0000000	67.0000000	499.0000000	633.0000000
Li	Li	2	0.0625000	0.0305000	0.0320000	0.0930000
V	V	2	7.1715000	1.5225000	5.6490000	8.6940000
Cr	Cr	2	8.9155000	0.7315000	8.1840000	9.6470000
Mn	Mn	2	5.7790000	0.7960000	4.9830000	6.5750000
Ni	Ni	2	6.8495000	1.8645000	4.9850000	8.7140000
Co	Co	2	0	0	0	0
Zn	Zn	2	202.5000000	35.0000000	167.5000000	237.5000000
As	As	2	0	0	0	0
Sr	Sr	2	8.1540000	1.7460000	6.4080000	9.9000000
Cd	Cd	2	0.3315000	0.1055000	0.2260000	0.4370000
Ba	Ba	2	15.8000000	1.1400000	14.6600000	16.9400000
Pb	Pb	2	0	0	0	0

----------------------------------- Sampling_Date=4 Station=3 -----------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	206.1950000	7.8550000	198.3400000	214.0500000
Al	Al	2	3572.00	88.0000000	3484.00	3660.00
Ca	Ca	2	19260.00	1220.00	18040.00	20480.00
Na	Na	2	1055.50	23.5000000	1032.00	1079.00
Mg	Mg	2	4323.50	86.5000000	4237.00	4410.00
Fe	Fe	2	3687.00	65.0000000	3622.00	3752.00
Li	Li	2	2.6210000	0.0740000	2.5470000	2.6950000
V	V	2	14.4150000	0.2950000	14.1200000	14.7100000
Cr	Cr	2	18.8700000	0.4100000	18.4600000	19.2800000
Mn	Mn	2	30.7400000	1.5000000	29.2400000	32.2400000
Ni	Ni	2	14.7600000	0.7600000	14.0000000	15.5200000
Co	Co	2	1.5190000	0.0620000	1.4570000	1.5810000
Zn	Zn	2	108.7600000	16.2400000	92.5200000	125.0000000
As	As	2	0	0	0	0
Sr	Sr	2	72.6850000	1.2450000	71.4400000	73.9300000
Cd	Cd	2	0.3840000	0.0330000	0.3510000	0.4170000
Ba	Ba	2	64.4300000	0.8800000	63.5500000	65.3100000
Pb	Pb	2	0.0395000	0.0395000	0	0.0790000

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----------------------------------- Sampling_Date=4 Station=4 -----------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	197.6550000	10.3050000	187.3500000	207.9600000
Al	Al	2	1769.50	19.5000000	1750.00	1789.00
Ca	Ca	2	13565.00	1395.00	12170.00	14960.00
Na	Na	2	641.0000000	12.3000000	628.7000000	653.3000000
Mg	Mg	2	2510.00	21.0000000	2489.00	2531.00
Fe	Fe	2	1951.50	24.5000000	1927.00	1976.00
Li	Li	2	1.5655000	0.4055000	1.1600000	1.9710000
V	V	2	14.2700000	0.3500000	13.9200000	14.6200000
Cr	Cr	2	12.2500000	0.0400000	12.2100000	12.2900000
Mn	Mn	2	17.6850000	0.6850000	17.0000000	18.3700000
Ni	Ni	2	11.6600000	0.5300000	11.1300000	12.1900000

Co	Co	2	0.0595000	0.0595000	0	0.1190000
Zn	Zn	2	127.0000000	22.6000000	104.4000000	149.6000000
As	As	2	0	0	0	0
Sr	Sr	2	47.4150000	0.8150000	46.6000000	48.2300000
Cd	Cd	2	0.3580000	0.0480000	0.3100000	0.4060000
Ba	Ba	2	37.8150000	0.1550000	37.6600000	37.9700000
Pb	Pb	2	0.4465000	0.4465000	0	0.8930000

------------------------------------ Sampling_Date=4 Station=5 ------------------------------------

Variable	Label	N	Mean	Std Error	Minimum	Maximum
PM10	PM10	2	124.9900000	3.8500000	121.1400000	128.8400000
Al	Al	2	757.3000000	6.8000000	750.5000000	764.1000000
Ca	Ca	2	5398.50	691.5000000	4707.00	6090.00
Na	Na	2	718.4000000	26.0000000	692.4000000	744.4000000
Mg	Mg	2	911.9500000	26.0500000	885.9000000	938.0000000
Fe	Fe	2	876.6000000	9.6000000	867.0000000	886.2000000
Li	Li	2	0.3865000	0.0235000	0.3630000	0.4100000
V	V	2	8.0390000	0.1330000	7.9060000	8.1720000
Cr	Cr	2	10.0900000	0.3900000	9.7000000	10.4800000
Mn	Mn	2	14.6545000	6.9555000	7.6990000	21.6100000
Ni	Ni	2	10.9510000	3.2990000	7.6520000	14.2500000
Co	Co	2	0	0	0	0
Zn	Zn	2	91.9550000	32.4450000	59.5100000	124.4000000
As	As	2	0	0	0	0
Sr	Sr	2	15.0500000	0.6100000	14.4400000	15.6600000
Cd	Cd	2	0.4530000	0.0880000	0.3650000	0.5410000
Ba	Ba	2	17.2950000	0.4550000	16.8400000	17.7500000
Pb	Pb	2	2.6715000	0.4845000	2.1870000	3.1560000

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: PM10 PM10

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	74132.18035	3901.69370	46.52	<.0001
Error	19	1593.39854	83.86308		
Corrected Total	38	75725.57889			

R-Square	Coeff Var	Root MSE	PM10 Mean
0.978958	5.811600	9.157679	157.5759

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	14926.39396	4975.46465	59.33	<.0001
Station	4	15609.27417	3902.31854	46.53	<.0001
Sampling_Date*Station	12	43596.51222	3633.04269	43.32	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Appendix C: Statistical Analysis

Sampling_Date	3	14750.06710	4916.68903	58.63	<.0001
Station	4	11465.15025	2866.28756	34.18	<.0001
Sampling_Date*Station	12	43596.51222	3633.04269	43.32	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	PM10 LSMEAN	LSMEAN Number
1	140.966754	1
2	159.668102	2
3	190.010837	3
4	145.297000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: PM10

i/j	1	2	3	4
1		0.0018	<.0001	0.7187
2	0.0018		<.0001	0.0164
3	<.0001	<.0001		<.0001
4	0.7187	0.0164	<.0001	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	PM10 LSMEAN	LSMEAN Number
1	166.996550	1
2	138.069631	2
3	182.590665	3
4	167.699318	4
5	139.572203	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: PM10

i/j	1	2	3	4	5
1		<.0001	0.0219	0.9999	0.0002
2	<.0001		<.0001	<.0001	0.9978
3	0.0219	<.0001		0.0303	<.0001
4	0.9999	<.0001	0.0303		0.0001
5	0.0002	0.9978	<.0001	0.0001	

The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Al Al

Sum of

Appendix C: Statistical Analysis

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	19	23263547.90	1224397.26	208.66	<.0001
Error	19	111491.69	5867.98		
Corrected Total	38	23375039.60			

R-Square	Coeff Var	Root MSE	Al Mean
0.995230	5.836652	76.60277	[illegible]

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	214361.17	71453.72	12.18	0.0001
Station	4	4566524.77	1141631.19	194.55	<.0001
Sampling_Date*Station	12	18482661.96	1540221.83	262.48	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	204703.70	68234.57	11.63	0.0001
Station	4	3735120.45	933780.11	159.13	<.0001
Sampling_Date*Station	12	18482661.96	1540221.83	262.48	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Al LSMEAN	LSMEAN Number
1	1303.01000	1
2	1268.72000	2
3	1248.29000	3
4	1433.71000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Al

i/j	1	2	3	4
1		0.7763	0.4036	0.0059
2	0.7763		0.9402	0.0010
3	0.4036	0.9402		0.0002
4	0.0059	0.0010	0.0002	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Al LSMEAN	LSMEAN Number
1	1160.01250	1
2	1285.03750	2
3	1736.12500	3
4	1571.65000	4
5	814.33750	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Al

i/j	1	2	3	4	5
1		0.0295	<.0001	<.0001	<.0001
2	0.0295		<.0001	<.0001	<.0001
3	<.0001	<.0001		0.0032	<.0001
4	<.0001	<.0001	0.0032		<.0001
5	<.0001	<.0001	<.0001	<.0001	

Appendix C: Statistical Analysis

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Ca Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	884411098.9	46547952.6	7.92	<.0001
Error	19	111630265.5	5875277.1		
Corrected Total	38	996041364.4			

R-Square	Coeff Var	Root MSE	Ca Mean
0.887926	23.72154	2423.897	[illegible]

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	26699502.0	8899834.0	1.51	0.2429
Station	4	181802359.7	45450589.9	7.74	0.0007
Sampling_Date*Station	12	675909237.2	56325769.8	9.59	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	25043603.8	8347867.9	1.42	0.2677
Station	4	109443812.8	27360953.2	4.66	0.0086
Sampling_Date*Station	12	675909237.2	56325769.8	9.59	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Ca LSMEAN	LSMEAN Number
1	10108.8000	1
2	10353.4000	2
3	11544.5000	3
4	9340.0000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ca

i/j	1	2	3	4
1		0.9964	0.5594	0.8922
2	0.9964		0.7242	0.8094
3	0.5594	0.7242		0.2109
4	0.8922	0.8094	0.2109	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Appendix C: Statistical Analysis

Station	Ca LSMEAN	LSMEAN Number
1	10796.2500	1
2	10277.3750	2
3	12386.6250	3
4	11174.8750	4
5	7048.2500	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ca

i/j	1	2	3	4	5
1		0.9924	0.6872	0.9977	0.0600
2	0.9924		0.4346	0.9441	0.1295
3	0.6872	0.4346		0.8522	0.0043
4	0.9977	0.9441	0.8522		0.0330
5	0.0600	0.1295	0.0043	0.0330	

The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Na Na

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	3034984.100	159736.005	11.38	<.0001
Error	19	266704.400	14037.074		
Corrected Total	38	3301688.500			

R-Square	Coeff Var	Root MSE	Na Mean
0.919222	16.82212	118.4782	704.3000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	345713.086	115237.695	8.21	0.0010
Station	4	166476.285	41619.071	2.96	0.0464
Sampling_Date*Station	12	2522794.729	210232.894	14.98	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	332588.518	110862.839	7.90	0.0013
Station	4	134491.488	33622.872	2.40	0.0865
Sampling_Date*Station	12	2522794.729	210232.894	14.98	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Na LSMEAN	LSMEAN Number

Appendix C: Statistical Analysis

1	814.650000	1
2	562.730000	2
3	666.600000	3
4	758.900000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Na

i/j	1	2	3	4
1		0.0012	0.0518	0.7216
2	0.0012		0.2738	0.0110
3	0.0518	0.2738		0.3307
4	0.7216	0.0110	0.3307	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Na LSMEAN	LSMEAN Number
1	777.562500	1
2	675.925000	2
3	733.300000	3
4	721.512500	4
5	595.300000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Na

i/j	1	2	3	4	5
1		0.4483	0.9424	0.8752	0.0618
2	0.4483		0.8658	0.9363	0.7042
3	0.9424	0.8658		0.9996	0.2233
4	0.8752	0.9363	0.9996		0.2994
5	0.0618	0.7042	0.2233	0.2994	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Mg Mg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	37652101.01	1981689.53	123.75	<.0001
Error	19	304258.64	16013.61		
Corrected Total	38	37956359.65			

R-Square Coeff Var Root MSE Mg Mean

Appendix C: Statistical Analysis

0.991984	6.234038	126.5449	2029.903

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	1379023.57	459674.52	28.71	<.0001
Station	4	8870803.83	2217700.96	138.49	<.0001
Sampling_Date*Station	12	27402273.60	2283522.80	142.60	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	1108454.15	369484.72	23.07	<.0001
Station	4	5652753.09	1413188.27	88.25	<.0001
Sampling_Date*Station	12	27402273.60	2283522.80	142.60	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Mg LSMEAN	LSMEAN Number
1	2093.61000	1
2	1975.32000	2
3	2302.45000	3
4	1847.94000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Mg

i/j	1	2	3	4
1		0.2254	0.0077	0.0018
2	0.2254		0.0001	0.1746
3	0.0077	0.0001		<.0001
4	0.0018	0.1746	<.0001	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Mg LSMEAN	LSMEAN Number
1	2037.00000	1
2	2010.31250	2
3	2623.62500	3
4	2217.40000	4
5	1385.81250	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Mg

i/j	1	2	3	4	5
1		0.9928	<.0001	0.0682	<.0001
2	0.9928		<.0001	0.0290	<.0001
3	<.0001	<.0001		<.0001	<.0001
4	0.0682	0.0290	<.0001		<.0001
5	<.0001	<.0001	<.0001	<.0001	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Appendix C: Statistical Analysis

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Fe Fe

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	21231355.17	1117439.75	231.34	<.0001
Error	19	91775.08	4830.27		
Corrected Total	38	21323130.25			

R-Square	Coeff Var	Root MSE	Fe Mean
0.995696	4.781317	69.50012	1453.577

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	353337.03	117779.01	24.38	<.0001
Station	4	4543275.31	1135818.83	235.15	<.0001
Sampling_Date*Station	12	16334742.84	1361228.57	281.81	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	327244.74	109081.58	22.58	<.0001
Station	4	3757882.32	939470.58	194.50	<.0001
Sampling_Date*Station	12	16334742.84	1361228.57	281.81	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Fe LSMEAN	LSMEAN Number
1	1330.45000	1
2	1422.99000	2
3	1515.58000	3
4	1568.23000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Fe

i/j	1	2	3	4
1		0.0474	<.0001	<.0001
2	0.0474		0.0472	0.0014
3	<.0001	0.0472		0.3540
4	<.0001	0.0014	0.3540	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Fe LSMEAN	LSMEAN Number
1	1241.41250	1
2	1408.12500	2
3	1956.25000	3
4	1647.73750	4
5	1043.03750	5

Appendix C: Statistical Analysis

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Fe

i/j	1	2	3	4	5
1		0.0011	<.0001	<.0001	0.0003
2	0.0011		<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001
5	0.0003	<.0001	<.0001	<.0001	

The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Li Li

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	20.35230340	1.07117386	30.88	<.0001
Error	19	0.65898450	0.03468339		
Corrected Total	38	21.01128790			

R-Square	Coeff Var	Root MSE	Li Mean
0.968637	18.09366	0.186235	1.029282

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0.67685700	0.22561900	6.51	0.0033
Station	4	3.95298271	0.98824568	28.49	<.0001
Sampling_Date*Station	12	15.72246369	1.31020531	37.78	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0.58269736	0.19423245	5.60	0.0063
Station	4	3.37661097	0.84415274	24.34	<.0001
Sampling_Date*Station	12	15.72246369	1.31020531	37.78	<.0001

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Li LSMEAN	LSMEAN Number
1	0.83460000	1
2	1.16360000	2
3	1.10060000	3
4	1.00530000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Li

Appendix C: Statistical Analysis

i/j	1	2	3	4
1		0.0066	0.0227	0.2054
2	0.0066		0.8874	0.2984
3	0.0227	0.8874		0.6676
4	0.2054	0.2984	0.6676	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Li LSMEAN	LSMEAN Number
1	1.28625000	1
2	0.92662500	2
3	1.28225000	3
4	1.17750000	4
5	0.45750000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Li

i/j	1	2	3	4	5
1		0.0082	1.0000	0.7689	<.0001
2	0.0082		0.0090	0.0924	0.0012
3	1.0000	0.0090		0.7916	<.0001
4	0.7689	0.0924	0.7916		<.0001
5	<.0001	0.0012	<.0001	<.0001	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: V V

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	389.1924830	20.4838149	40.60	<.0001
Error	19	9.5865680	0.5045562		
Corrected Total	38	398.7790510			

R-Square	Coeff Var	Root MSE	V Mean
0.975960	6.247892	0.710321	11.36897

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	181.5128801	60.5042934	119.92	<.0001
Station	4	77.9308922	19.4827231	38.61	<.0001
Sampling_Date*Station	12	129.7487107	10.8123926	21.43	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Appendix C: Statistical Analysis

Sampling_Date	3	174.2109322	58.0703107	115.09	<.0001
Station	4	78.4454226	19.6113556	38.87	<.0001
Sampling_Date*Station	12	129.7487107	10.8123926	21.43	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	V LSMEAN	LSMEAN Number
1	8.5670000	1
2	12.6550000	2
3	13.9810000	3
4	10.1890000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: V

i/j	1	2	3	4
1		<.0001	<.0001	0.0003
2	<.0001		0.0041	<.0001
3	<.0001	0.0041		<.0001
4	0.0003	<.0001	<.0001	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	V LSMEAN	LSMEAN Number
1	10.5150000	1
2	10.2912500	2
3	12.9310000	3
4	13.2272500	4
5	9.7755000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: V

i/j	1	2	3	4	5
1		0.9683	<.0001	<.0001	0.3203
2	0.9683		<.0001	<.0001	0.6535
3	<.0001	<.0001		0.9166	<.0001
4	<.0001	<.0001	0.9166		<.0001
5	0.3203	0.6535	<.0001	<.0001	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Cr Cr

Appendix C: Statistical Analysis

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	243.9559309	12.8397858	7.69	<.0001
Error	19	31.7312030	1.6700633		
Corrected Total	38	275.6871339			

R-Square	Coeff Var	Root MSE	Cr Mean
0.884901	9.908282	1.292309	13.04272

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	16.8544694	5.6181565	3.36	0.0403
Station	4	79.7085072	19.9271268	11.93	<.0001
Sampling_Date*Station	12	147.3929543	12.2827462	7.35	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	16.4240258	5.4746753	3.28	0.0435
Station	4	71.3278988	17.8319747	10.68	0.0001
Sampling_Date*Station	12	147.3929543	12.2827462	7.35	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Cr LSMEAN	LSMEAN Number
1	12.8640000	1
2	13.6844000	2
3	13.6070000	3
4	12.0682000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Cr

i/j	1	2	3	4
1		0.5420	0.5827	0.5281
2	0.5420		0.9992	0.0668
3	0.5827	0.9992		0.0673
4	0.5281	0.0668	0.0673	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Cr LSMEAN	LSMEAN Number
1	12.3413750	1
2	13.1826250	2
3	15.4987500	3
4	12.9455000	4
5	11.3112500	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Cr

i/j	1	2	3	4	5
1		0.6933	0.0009	0.8797	0.5729
2	0.6933		0.0150	0.9958	0.0862
3	0.0009	0.0150		0.0068	<.0001
4	0.8797	0.9958	0.0068		0.1625

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           5        0.5729        0.0862        <.0001        0.1625
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                                  The GLM Procedure

                               Class Level Information

                         Class          Levels    Values

                         Sampling_Date           4    1 2 3 4

                         Station             5    1 2 3 4 5


                             Number of observations    40

NOTE: Due to missing values, only 39 observations can be used in this analysis.
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                                  The GLM Procedure

Dependent Variable: Mn   Mn

                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                       19     1886.967016       99.314053      15.53    <.0001

      Error                       19      121.469089        6.393110

      Corrected Total             38     2008.436105


                       R-Square     Coeff Var      Root MSE       Mn Mean

                       0.939521      15.34245      2.528460      16.48015


      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Sampling_Date                    3       38.170892       12.723631       1.99    0.1496
      Station                      4      295.616110       73.904027      11.56    <.0001
      Sampling_Date*Station           12      1553.180014      129.431668      20.25    <.0001


      Source                      DF     Type III SS     Mean Square    F Value    Pr > F

      Sampling_Date                    3       34.901303       11.633768       1.82    0.1778
      Station                      4      217.216378       54.304095       8.49    0.0004
      Sampling_Date*Station           12      1553.180014      129.431668      20.25    <.0001
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                                  The GLM Procedure
                                 Least Squares Means
                       Adjustment for Multiple Comparisons: Tukey-Kramer

                                                     LSMEAN
                           Sampling_Date       Mn LSMEAN      Number

                           1             17.4878000          1
                           2             16.0870000          2
                           3             17.3597000          3
                           4             15.2171000          4


                          Least Squares Means for effect Sampling_Date
                            Pr > |t| for H0: LSMean(i)=LSMean(j)

                                 Dependent Variable: Mn

                  i/j              1             2             3             4

                     1                      0.6456        0.9995        0.2199
                     2        0.6456                      0.7095        0.8824
                     3        0.9995        0.7095                      0.2632
                     4        0.2199        0.8824        0.2632
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                                  The GLM Procedure
                                 Least Squares Means
```

Appendix C: Statistical Analysis

Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Mn LSMEAN	LSMEAN Number
1	15.1130000	1
2	18.4185000	2
3	19.2137500	3
4	17.5275000	4
5	12.4167500	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Mn

i/j	1	2	3	4	5
1		0.1073	0.0308	0.3458	0.2985
2	0.1073		0.9684	0.9529	0.0021
3	0.0308	0.9684		0.6745	0.0006
4	0.3458	0.9529	0.6745		0.0092
5	0.2985	0.0021	0.0006	0.0092	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Ni Ni

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	209.4767362	11.0250914	4.27	0.0014
Error	19	49.0986975	2.5841420		
Corrected Total	38	258.5754337			

R-Square	Coeff Var	Root MSE	Ni Mean
0.810118	14.72609	1.607527	10.91618

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	18.0696912	6.0232304	2.33	0.1067
Station	4	56.9170730	14.2292683	5.51	0.0041
Sampling_Date*Station	12	134.4899721	11.2074977	4.34	0.0023

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	18.2529754	6.0843251	2.35	0.1042
Station	4	55.1353411	13.7838353	5.33	0.0047
Sampling_Date*Station	12	134.4899721	11.2074977	4.34	0.0023

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

LSMEAN

Appendix C: Statistical Analysis

Sampling_Date	Ni LSMEAN	Number
1	10.7868000	1
2	12.0100000	2
3	11.0038000	3
4	10.0195000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ni

i/j	1	2	3	4
1		0.3904	0.9901	0.7129
2	0.3904		0.5534	0.0703
3	0.9901	0.5534		0.5327
4	0.7129	0.0703	0.5327	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Ni LSMEAN	LSMEAN Number
1	9.3288750	1
2	10.5756250	2
3	12.7145000	3
4	11.8037500	4
5	10.3523750	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ni

i/j	1	2	3	4	5
1		0.5441	0.0038	0.0432	0.7511
2	0.5441		0.0983	0.5579	0.9989
3	0.0038	0.0983		0.7874	0.0798
4	0.0432	0.5579	0.7874		0.4558
5	0.7511	0.9989	0.0798	0.4558	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Co Co

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	4.71241444	0.24802181	9.65	<.0001
Error	19	0.48851900	0.02571153		
Corrected Total	38	5.20093344			

R-Square Coeff Var Root MSE Co Mean

Appendix C: Statistical Analysis

0.906071	106.7163	0.160348	0.150256

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0.42176928	0.14058976	5.47	0.0070
Station	4	1.22506957	0.30626739	11.91	<.0001
Sampling_Date*Station	12	3.06557559	0.25546463	9.94	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0.42187277	0.14062426	5.47	0.0070
Station	4	1.21108958	0.30277240	11.78	<.0001
Sampling_Date*Station	12	3.06557559	0.25546463	9.94	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Co LSMEAN	LSMEAN Number
1	0.07640000	1
2	0.14020000	2
3	0.05370000	3
4	0.31570000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Co

i/j	1	2	3	4
1		0.8308	0.9887	0.0167
2	0.8308		0.6641	0.1255
3	0.9887	0.6641		0.0084
4	0.0167	0.1255	0.0084	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Co LSMEAN	LSMEAN Number
1	0.06150000	1
2	0.09550000	2
3	0.49350000	3
4	0.08200000	4
5	0.00000000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Co

i/j	1	2	3	4	5
1		0.9927	0.0003	0.9990	0.9485
2	0.9927		0.0007	0.9998	0.7926
3	0.0003	0.0007		0.0005	0.0001
4	0.9990	0.9998	0.0005		0.8676
5	0.9485	0.7926	0.0001	0.8676	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4

Appendix C: Statistical Analysis

Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Zn Zn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	88168.4780	4640.4462	1.17	0.3687
Error	19	75435.4803	3970.2884		
Corrected Total	38	163603.9583			

R-Square	Coeff Var	Root MSE	Zn Mean
0.538914	47.59707	63.01022	132.3826

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	4209.94949	1403.31650	0.35	0.7872
Station	4	32294.14010	8073.53503	2.03	0.1303
Sampling_Date*Station	12	51664.38845	4305.36570	1.08	0.4235

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	4211.96769	1403.98923	0.35	0.7870
Station	4	28409.23062	7102.30766	1.79	0.1728
Sampling_Date*Station	12	51664.38845	4305.36570	1.08	0.4235

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Zn LSMEAN	LSMEAN Number
1	148.941000	1
2	133.149000	2
3	124.542000	3
4	123.160000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Zn

i/j	1	2	3	4
1		0.9496	0.8222	0.7972
2	0.9496		0.9911	0.9863
3	0.8222	0.9911		1.0000
4	0.7972	0.9863	1.0000	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Zn LSMEAN	LSMEAN Number
1	170.130000	1
2	153.472500	2
3	106.540000	3
4	135.358750	4
5	96.738750	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Zn

i/j	1	2	3	4	5
1		0.9832	0.2951	0.8025	0.2233
2	0.9832		0.5810	0.9772	0.4584
3	0.2951	0.5810		0.8877	0.9982
4	0.8025	0.9772	0.8877		0.7754
5	0.2233	0.4584	0.9982	0.7754	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: As As

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	0	0	.	.
Error	19	0	0		
Corrected Total	38	0			

R-Square	Coeff Var	Root MSE	As Mean
0.000000	.	0	0

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0	0	.	.
Station	4	0	0	.	.
Sampling_Date*Station	12	0	0	.	.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	0	0	.	.
Station	4	0	0	.	.
Sampling_Date*Station	12	0	0	.	.

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	As LSMEAN	LSMEAN Number
1	0	1
2	0	2
3	0	3
4	0	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Appendix C: Statistical Analysis

Dependent Variable: As

i/j	1	2	3	4
1		.	.	.
2	.		.	.
3	.	.		.
4	.	.	.	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	As LSMEAN	LSMEAN Number
1	0	1
2	0	2
3	0	3
4	0	4
5	0	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: As

i/j	1	2	3	4	5
1		.	.	.	.
2	.		.	.	.
3	.	.		.	.
4	.	.	.		.
5	.	.	.	.	

The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

The GLM Procedure

Dependent Variable: Sr Sr

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	9521.768429	501.145707	26.85	<.0001
Error	19	354.668344	18.666755		
Corrected Total	38	9876.436774			

R-Square	Coeff Var	Root MSE	Sr Mean
0.964089	13.87190	4.320504	31.14572

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	194.875742	64.958581	3.48	0.0363
Station	4	2432.757589	608.189397	32.58	<.0001
Sampling_Date*Station	12	6894.135099	574.511258	30.78	<.0001

Appendix C: Statistical Analysis

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	143.122858	47.707619	2.56	0.0857
Station	4	1889.318109	472.329527	25.30	<.0001
Sampling_Date*Station	12	6894.135099	574.511258	30.78	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Sampling_Date	Sr LSMEAN	LSMEAN Number
1	29.2990000	1
2	31.3320000	2
3	34.5945000	3
4	31.4608000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Sr

i/j	1	2	3	4
1		0.7494	0.0577	0.6827
2	0.7494		0.3969	0.9999
3	0.0577	0.3969		0.3906
4	0.6827	0.9999	0.3906	

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Sr LSMEAN	LSMEAN Number
1	26.7837500	1
2	27.3835000	2
3	43.5925000	3
4	35.6587500	4
5	24.9393750	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Sr

i/j	1	2	3	4	5
1		0.9986	<.0001	0.0048	0.9259
2	0.9986		<.0001	0.0088	0.8209
3	<.0001	<.0001		0.0124	<.0001
4	0.0048	0.0088	0.0124		0.0014
5	0.9259	0.8209	<.0001	0.0014	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Cd Cd

Appendix C: Statistical Analysis

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                                      Sum of
Source                      DF       Squares     Mean Square    F Value    Pr > F

Model                       19    0.40132374      0.02112230       1.54    0.1757

Error                       19    0.25980800      0.01367411

Corrected Total             38    0.66113174


                 R-Square     Coeff Var      Root MSE       Cd Mean

                 0.607025      36.94521      0.116936      0.316513


Source                      DF     Type I SS     Mean Square    F Value    Pr > F

Sampling_Date                    3      0.19496072      0.06498691       4.75    0.0123
Station                     4     0.10711360      0.02677840       1.96    0.1421
Sampling_Date*Station          12      0.09924942      0.00827079       0.60    0.8125


Source                      DF   Type III SS     Mean Square    F Value    Pr > F

Sampling_Date                    3      0.20310478      0.06770159       4.95    0.0105
Station                     4     0.09492031      0.02373008       1.74    0.1838
Sampling_Date*Station          12      0.09924942      0.00827079       0.60    0.8125
```



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                             The GLM Procedure
                            Least Squares Means
                 Adjustment for Multiple Comparisons: Tukey-Kramer

                                                   LSMEAN
                       Sampling_Date       Cd LSMEAN      Number

                       1             0.24180000          1
                       2             0.24480000          2
                       3             0.41280000          3
                       4             0.35080000          4


                     Least Squares Means for effect Sampling_Date
                       Pr > |t| for H0: LSMean(i)=LSMean(j)

                              Dependent Variable: Cd

           i/j              1             2             3             4

              1                      0.9999        0.0193        0.1939
              2        0.9999                      0.0298        0.2481
              3        0.0193        0.0298                      0.6429
              4        0.1939        0.2481        0.6429
```



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                             The GLM Procedure
                            Least Squares Means
                 Adjustment for Multiple Comparisons: Tukey-Kramer

                                                  LSMEAN
                        Station        Cd LSMEAN      Number

                        1           0.26512500          1
                        2           0.25100000          2
                        3           0.38212500          3
                        4           0.31700000          4
                        5           0.34750000          5


                       Least Squares Means for effect Station
                        Pr > |t| for H0: LSMean(i)=LSMean(j)

                              Dependent Variable: Cd

    i/j              1             2             3             4             5

       1                      0.9992        0.3028        0.8981        0.6778
       2        0.9992                      0.2069        0.7896        0.5411
       3        0.3028        0.2069                      0.7973        0.9795
```

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              4        0.8981        0.7896        0.7973                        0.9872
              5        0.6778        0.5411        0.9795        0.9872
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                                The GLM Procedure

                             Class Level Information

                       Class          Levels    Values

                       Sampling_Date          4    1 2 3 4

                       Station            5    1 2 3 4 5


                           Number of observations    40

NOTE: Due to missing values, only 39 observations can be used in this analysis.
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                                The GLM Procedure

Dependent Variable: Ba   Ba

                                        Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F

      Model                       19     7509.320847      395.227413      80.66    <.0001

      Error                       19       93.100450        4.900024

      Corrected Total             38     7602.421297


                       R-Square     Coeff Var      Root MSE       Ba Mean

                       0.987754      6.679592      2.213600      33.13974


      Source                      DF       Type I SS     Mean Square    F Value    Pr > F

      Sampling_Date                    3      1828.493749       609.497916      124.39    <.0001
      Station                     4     1960.283061      490.070765     100.01    <.0001
      Sampling_Date*Station          12      3720.544037       310.045336       63.27    <.0001


      Source                      DF     Type III SS     Mean Square    F Value    Pr > F

      Sampling_Date                    3      1908.052679      636.017560     129.80    <.0001
      Station                     4     1865.247614      466.311904      95.17    <.0001
      Sampling_Date*Station          12      3720.544037      310.045336      63.27    <.0001
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                                The GLM Procedure
                               Least Squares Means
                       Adjustment for Multiple Comparisons: Tukey-Kramer

                                                   LSMEAN
                          Sampling_Date       Ba LSMEAN      Number

                          1             24.7770000          1
                          2             36.6350000          2
                          3             43.2930000          3
                          4             30.2340000          4


                          Least Squares Means for effect Sampling_Date
                            Pr > |t| for H0: LSMean(i)=LSMean(j)

                               Dependent Variable: Ba

                    i/j              1             2             3             4

                       1                      <.0001        <.0001        0.0001
                       2        <.0001                      <.0001        <.0001
                       3        <.0001        <.0001                      <.0001
                       4        0.0001        <.0001        <.0001
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                                The GLM Procedure
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Appendix C: Statistical Analysis

Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Ba LSMEAN	LSMEAN Number
1	29.0150000	1
2	27.8762500	2
3	46.8775000	3
4	31.8850000	4
5	33.0200000	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Ba

i/j	1	2	3	4	5
1		0.8390	<.0001	0.1116	0.0216
2	0.8390		<.0001	0.0138	0.0026
3	<.0001	<.0001		<.0001	<.0001
4	0.1116	0.0138	<.0001		0.8666
5	0.0216	0.0026	<.0001	0.8666	

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The GLM Procedure

Class Level Information

Class	Levels	Values
Sampling_Date	4	1 2 3 4
Station	5	1 2 3 4 5

Number of observations 40

NOTE: Due to missing values, only 39 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Pb Pb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	172.0626412	9.0559285	7.47	<.0001
Error	19	23.0411820	1.2126938		
Corrected Total	38	195.1038232			

R-Square	Coeff Var	Root MSE	Pb Mean
0.881903	67.83505	1.101224	1.623385

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Sampling_Date	3	39.5687633	13.1895878	10.88	0.0002
Station	4	24.3059398	6.0764849	5.01	0.0063
Sampling_Date*Station	12	108.1879381	9.0156615	7.43	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sampling_Date	3	43.0242452	14.3414151	11.83	0.0001
Station	4	25.6547376	6.4136844	5.29	0.0049
Sampling_Date*Station	12	108.1879381	9.0156615	7.43	<.0001

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The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Appendix C: Statistical Analysis

Sampling_Date	Pb LSMEAN	LSMEAN Number
1	0.65810000	1
2	2.98340000	2
3	2.54420000	3
4	0.63150000	4

Least Squares Means for effect Sampling_Date
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Pb

i/j	1	2	3	4
1		0.0013	0.0057	0.9999
2	0.0013		0.8298	0.0011
3	0.0057	0.8298		0.0051
4	0.9999	0.0011	0.0051	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

Station	Pb LSMEAN	LSMEAN Number
1	2.47962500	1
2	1.60675000	2
3	1.84037500	3
4	0.21537500	4
5	2.37937500	5

Least Squares Means for effect Station
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Pb

i/j	1	2	3	4	5
1		0.5238	0.7726	0.0047	0.9998
2	0.5238		0.9927	0.1261	0.6809
3	0.7726	0.9927		0.0559	0.8845
4	0.0047	0.1261	0.0559		0.0115
5	0.9998	0.6809	0.8845	0.0115	