Health Impacts of Particulate Matter in Greater Cairo, Egypt

A.A. Shakour[1], M.F. El-Shahat[2], N.M. El-Taieb[1], M.A. Hassanein[1], A.M.F. Mohamed[1]

[1]Air Pollution Department, Environment research Division, National Research Center, Cairo, Egypt.
[2] Chemistry Department, Faculty of science, Ain Shams University, Cairo, Egypt.
ateffathy2006@yahoo.com

Abstract: Airborne particulate matter samples (PM) were collected over two years (2008-2009) to investigate the levels of particulate matter in the selected sites. The selected sites were chosen to present different activities at north and south areas of Cairo City. Air-Q 2.2.3 model developed by WHO was used for the first time in this study to calculate the risk on human communities as result of PM exposure. The out put result showed that quantifying the impact of air pollution on the public's health has become an increasingly critical component in policy discussion. Those responsible for any health impact assessment must address important methodological issues related to both its design and conduct. The current study investigated the health effects of particulate matter exposure and respiratory diseases in Greater Cairo-Egypt. From the obtained results we conclude Air-Q model is valid to be used as a wide scale to evaluate the health impacts of air pollutants especially particulate matter. The current data recommends using of these models for policy makers and regulations as it can be use for the local authorities to decide on the necessity of reclamation of the two sites and the level of priority of the intervention, with respect to situation of other polluted areas.
[A.A. Shakour, M.F. El-Shahat[2], N.M. El-Taieb, M.A. Hassanein, A.M.F. Mohamed. **Health impacts of Particulate matter in Greater Cairo, Egypt**. Journal of American Science 2011; 7(9):840-848].(ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Air pollution, Particulate matter, Public Health, Air Q, Respiratory disease, Epidemiology Guidelines.

1. Introduction

Recent developments in the Cairo during the late 1950s and 1960s saw the city expand into a metropolitan region and becoming a center for modern and heavy industrial activity (EEAA, 2008). Two peripheral districts with agrarian based communities (Helwan in the South and Shoubra El--Kheima in the North) offered themselves as prime locations for the development of large modern industrial conglomerates (EEAA, 2008).

Airborne suspended particulate matter is an important marker of air quality. Particles are emitted into the atmosphere from numerous natural and man-made sources and are also formed upon condensation of gases and vapors (Kleinman et al, 1980; Miguel et al, 1986; Hassan, 2006; Paoletti et al. 1989). Anthropogenic airborne particulate matter comes from a variety of sources which include traffic, industries, commerce and domestic heating and cooking (Han and Naher, 2006). Suspended particulate matter (SPM) varies in size, ranging from a diameter of 0.0002 µm to 500 µm (Hassan 2006). Particles having an aerodynamic diameter larger than 2.5 µm form the coarse particle fraction, particles having an aerodynamic diameter less than 2.5 µm form the fine particle fraction, and particles having <0.1µm in aerodynamic diameter are classified as ultra fine particles (Hassan 2006). The coarse fraction is mainly due to crustal material, paved road dust, non-catalyst equipped gasoline engines and back-ground sea salts, while the fine fraction is emitted from anthropogenic rather than natural sources or formed by vapour nucleation/condensation mechanisms (Hassan 2006). The lifetime of particulates varies from a few seconds to several months, depending upon their settling rate, size, density of particles, and air turbulence. Clouds of very fine particles may drift for hundreds to thousands of kilometers and cause pollution at large distance from where they were emitted; while the coarse particles travel less than one to tens of kilometers (USEPA, 1995a). The larger size particles are greatly affected by gravity and fine particles are more affected by diffusion (Chan and Kwok, 2000; Hassan 2006).

Suspended particulate matter can be categorized into primary and secondary aerosols: i) Primary aerosols include emission from pilot power plants, auto mobile exhaust, sea spray, and dust storm, and are emitted into the atmosphere directly from the source. ii) Secondary aerosols are produced in the atmosphere from reactions involving primary or secondary gases (Chow et al., 1993, 1994 and US EPA, 1995a).

Many epidemiological studies have found that statistical association between health outcomes and particulate matter concentrations; Fine particles rather than coarse particles are considered to be responsible for respiratory health effects. The debate over the scientific evidence for an underlying cause linking the level of airborne particles to adverse health effects has been intensified in recent years. Sources of both primary ad secondary particles will need to be controlled.

Cairo city centers, the annual mean concentrations of SPM were ranged between 355.0 and 365.5 μg/m^3 during 1994 to 1996, respectively (Khoder, 1997). Hassan (2000) found that, the annual mean concentrations of particulate matter at two urban areas of Cairo city were 339.75 and 262.5 μg/ m^3. The annual mean concentration of particulate matter at Cairo city during the year 1997 was 454.94 μg/ m^3 (Saleh, 2002). However particulate matter concentration ranged from 170 to 515 μg/m^3, with a mean value of 346.7 μg/m^3, during smog episodes, whereas it varied from 154 to 231.1 μg/m^3, with a mean value of 189.5 μg/m^3 during normal conditions in Cairo city (Abdel Hameed, 2003). In addition, Hassan (2006) reported that, the concentrations of TSP over Greater Cairo during 2001 to 2002 varied between 769-511 μg/m^3. Ezzo, (2006) found that, particulate matter concentration in industrial Sadat city during 2002 to 2003 was ranged from 226 to 516.3 μg/m^3. The annual inhaled particulates concentrations during five years (2004-2008), and shows that despite the high average annual concentrations during 2008 which exceeds the annual average permissible limits of Egyptian Environment Law (70 μg/m^3) (as shown in Table-1), it is less than the annual average concentrations which were monitored during the previous years which were about 137 μg/m^3 during 2008 and 151 μg/m^3 during 2007 (EEAA, 2008).

There is a strong link between elevated particle concentration and increased mortality and morbidity (WHO, 2004). Exposure to particulate matter can aggravate chronic respiratory and cardiovascular diseases, alter host defenses, damage lung tissue, lead to premature death, and possible contribute to cancer (WHO, 2004; Hassan, 2006). Particle shape and size are critical factors controlling the extent to which particles can penetrate into the respiratory tract, how and where particles are deposited, and at what rate particles are cleared form respiratory tract. Furthermore, a large number of smaller particles have a greater reactive surface area than an equivalent mass of larger particles and have a higher likelihood of reaching the deepest regions of the lungs, namely the alveolar region. Ultrafine airborne particles below 1 μm in diameter have been related to premature death, aggravated asthma, increased hospital admissions, and increased respiratory problems (Hassan, 2006).

Epidemiological methods provide the opportunity to study pollutants and interactions in complex environments within this framework. Assessments differ with the different mechanisms (allergic, infective or irritant/toxic). Epidemiological investigators can study effects of real-life exposures in various population subgroups, even though it may be difficult to attribute the specific adverse health effects observed to concentrations of any one pollutant.

Table 1: Ambient Air Quality Limit values as given by Law no.4 for Egypt (1994) compared to Reference Standards and Guidelines for Average Ambient Particulate Concentration (micrograms per cubic meter).

Standard or guideline	(annual)		(24 hours)	
	Suspended particulate (PM_{10})	TSP	Suspended particulate (PM_{10})	TSP
EU limit values	-	150	-	300
EU guide values	-	-	-	-
USEPA primary and secondary standards	50	-	150	-
WHO guidelines	-	60-90	-	150-230
WHO guidelines for Europe	50	70	125	-
National Ambient Air Quality Standards	-	-	150	-
Egyptian limit	70	90	-	230

Source: WHO, 1979; WHO, 1987; USEPA, 1990; European Community 1992 (EU); EEAA, 1994, 2008; EPA, 2010.

2. Materials and Methods

2.1. Study area

Greater Cairo Urban Region (GCUR) (30.08_N, 31.34_E) is the most populous region In Africa with over 18 million inhabitants (PRIDE, 1994). Geographically, the Region lies at an average elevation of 74 m (north) to 125 m above sea level (South) and has a fan shaped layout (Figure-1) (WHO/UNEP, 1992; PRIDE, 1994 and El-Dars et al, 2004). The City is bordered from the east by the Mokattam Hills separating the city from the Eastern Desert and, to the west, the Abu-Rawash Hills and the Western Desert. To The region's north lies the Nile Delta and to its south, a string of largely agricultural Towns along the Nile.

In this study, two locations selected were: Helwan (South) and Shoubra El-Khayma (North) (Figure-1), which contain two thermal power plants and range from industrial, mixed industrial/residential and residential regional Sub-districts. Helwan (South of Cairo city) and Shoubra El- Kheima (North of Cairo city) were agricultural areas that supplied crops to meet the needs of the capital city and its suburbs (PRIDE, 1994; El-Dars et al, 2004). Shoubra El-Kheima industrial complex is at the northern boundary of the city of Cairo. It has an area of about 30 Km^2 and houses over 800 industrial plants of various sizes. Textile manufacturing is the predominant activity, followed by engineering construction, glasses, chemical fertilizes, petroleum and electrical industries. The area, also, accommodates two big thermal power generating plants. Emissions from these industries and activities directly affect the air quality in the Greater Cairo area (Hassan, 2006). As well, Helwan Itself was being developed as a touristic area during the late 1930s to 1940s, the date of the commissioning of the national wax museum therein. However, during the 1950s and 1960s national industrial movement, these spacious and secluded districts were gradually transformed into industrialized centers. Currently, they all exhibit a high rate industrial activity and equally high population densities that were incurred by randomized urbanization and an increase in rural urban migration. More recently, Helwan was chosen in 1995 as the permanent Home for Helwan University, a national institution with over 102 000 students and 60 000 employees, staff and academics (El-Dars et al, 2004).

2.2. Sampling

The suspended particulate matter were collected through glass fiber filters of Whatmann GFA type (12 cm in radius) with 99% collection efficiency (Hassan, 2006) using medium volume samplers. The average rate of sampling is 14-18 L/min. (0.014-0.018 m^3/min) for twenty four hour sampling occurred from 10 a.m. – 10 a.m. day by day per week at the investigated sites starting from December 2008 to November 2009.

2.3. AirQ2.3 Model Inputs (WHO, 2010)

The programme needs the following data for running (Table-2):

1. Introductory data.
2. Pollutant data, in the current study particulate matter (PM) were used.
3. Cairo city coordinates.
4. Exposed population.
5. Air Quality Data such as: annual mean, winter mean, summer mean, annual maximum, winter maximum, summer maximum (for each site).
6. Calculate Relative Risk (RR) manually Using The Following equation:

$$RR = \exp [B (X - Xo)] \quad \text{source: WHO, 2004}$$

B = 0.0006 - 0.0010 (mean 0.0008)

X = annual mean concentration (ug/ m3)

Xo = baseline (threshold) concentration (ug/m3)

In this equation low, high and the mean value of constant B used the difference in concentration between annual mean concentration of particulate matter for investigated sites and limitation in Egyptian law 4 for year 1994. From calculation, we will get a low, high and mean relative risk for each site.

7. Health data such as: health end point (hospital admissions respiratory diseases), baseline incidence (Ministry Of Health, 2009), relative risk (mean, lower and upper) from previous equation, scientific certainty of relative risk (choice unknown), calculate impact of concentrations > 10 ug/m^3, calculate impact estimates to estimate number of excess cases for mean, lower and upper relative risk.

2.4. AirQ2.3 Model Outputs

AirQ2.3 model estimates impacts such as: Estimate number of cases per 100000/year for each concentration range and each relative risk for each site and calculate particulate matter 2009 hospital admissions respiratory diseases.

3. Results and Discussion

Table (3) shows the descriptive statistical analysis of SPM concentrations at sites-1 (North Shoubra El-Kheima), sites-2 (South Shoubra El-Kheima), sites-3 (North Helwan) and sites-4 (South Helwan) during the period of study. This table clearly indicates that the concentrations of SPM vary from season to another. The maximum concentration of SPM was 761±55 μg/m^3 at sites-4 (South Helwan) during winter season. While, the minimum value of SPM was 228±30 μg/m^3 at site-1 (North Shoubra El-Kheima) it was measured during summer season. The higher concentration of SPM during winter than summer season may be attributed to relatively low wind speed and higher frequency of inversions occurring in winter, leading to a decrease in the dispersion particulate matters. On the other hand, the high wind speed and higher atmospheric thermal turbulence due to high temperature gradients during summer season lead to increase the dispersion and dilution of SPM, in turn and the concentration of SPM was decreased. This result is in agreement with

Hassanien and Horvath (1995); Shakour and Zakey (1996); Khoder (1997); Saleh (2002); Ezoo (2006); Hassan (2006); El-Mekawy (2007) and El-Hashemy (2010).

The current annual mean concentration of SPM is approximately more than 10.2 times the EPA yearly air quality standard for TSP, 75 µg/m^3 (USEPA, 1974) and more than 8.4 times the Egyptian ambient air quality standard (90 µg/m^3, as annual mean, EEAA, 1994) (as shown in table-1). The high annual mean concentration of SPM is attributed to local emission from the industrial processes. Studied areas were very close to the main road which is characterized by heavy traffic during the day hours with private and commercial cars, lorries, busses, microbuses beside auto exhaust.

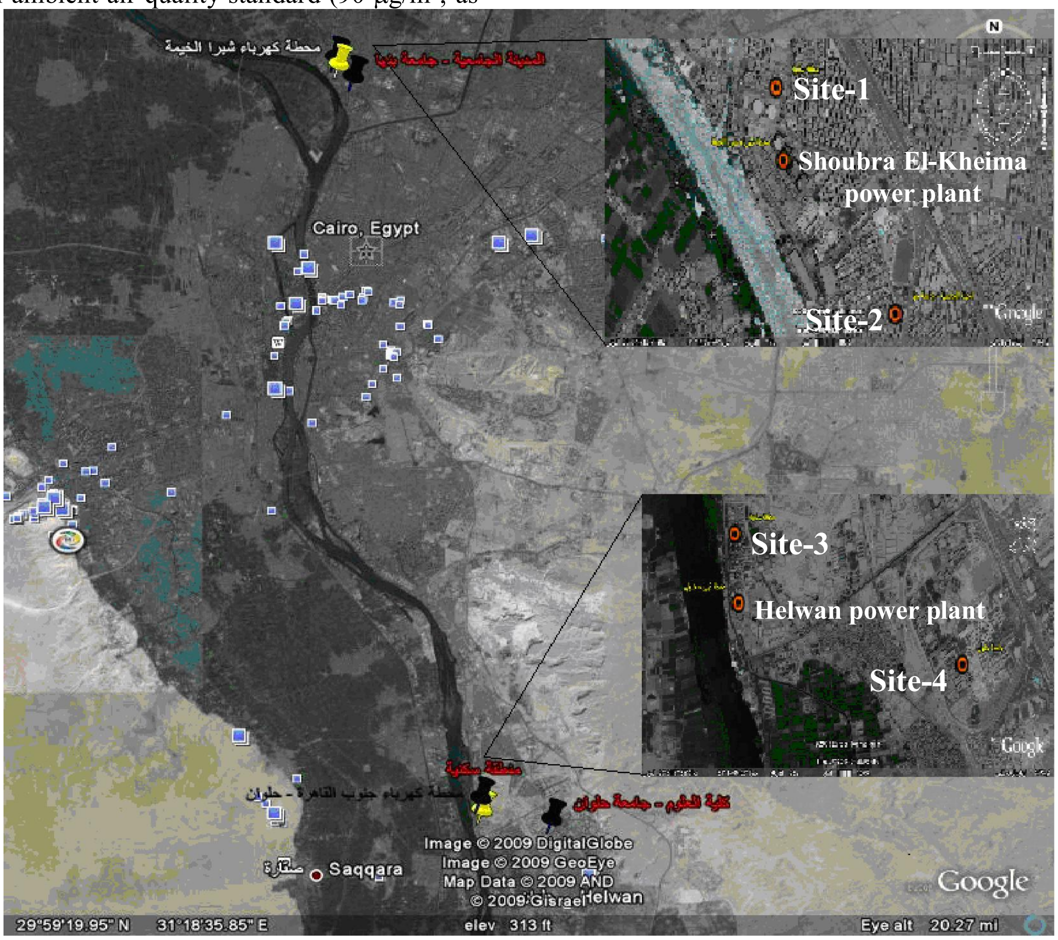

Figure (1): Investigated sites in Shoubra El-Kheima and Helwan areas in Cairo

Table (2): Air-Q2.2.3 model inputs

Input Data	Value
Country name	Egypt
City	Cairo
Year	2008 - 2009
Pollutant	PM
Cairo coordinates	Latitude 30.0833 and Longitude 31.2833*
Exposed population	17290000 person*
Cumulative concentration	0 to $\leq$ 400 ug/m^3
Baseline incidence	4300 case per 100000 person per year**

(Source: * CAPMAS, 2011, ** Ministry Of Health, 2009)

Table (3): Seasonal and annual mean concentrations (ug/m^3) for sites in Shoubra El-Kheima and Helwan areas during study period

parameter		Site-1	site-2	site-3	site-4
Max.	Win.	422	685	685	761
	Sum.	303	499	494	761
	Ann.	422	685	685	757
Min.	Win.	293	490	486	739
	Sum.	228	267	382	441
	Ann.	228	267	382	441
Mean	Win.	372	614	665	697
	Sum.	297	495	494	747
	Ann.	306	493	515	623
St. Dev.	Win.	34	71	86	55
	Sum.	30	66	56	153
	Ann.	49	88	100	120
Relative Risk (RR)	Ann.	1.138 (95% CI: 1.189-1.241)	1.274 (95% CI: 1.380-1.496)	1.290 (95% CI: 1.405-1.530)	1.377 (95% CI: 1.532-1.704)

Site – 1: North Shoubra El-Kheima, Site – 2: South Shoubra El-Kheima, Site – 3: North Helwan, Site – 4: South Helwan.

Table (3) also show a high concentration of SPM at Helwan (site-3 and site-4). The concentration ranged from 515 to 623 ug/m^3. This high concentration of SPM might be attributed to the presence of three cement production factories, coke, iron and steel factory, nonferrous metallurgical factory in addition to many other industries in and around this area that emit large amount of fine particulate to the atmosphere beside thermal power station working by heavy oil as main fuel. These values are generally in a good agreement with Ibrahim (1992) and Hindy et al. (1990).

Also, it is in agreement with Soliman and Borai (2001) and Shakour et al. (2001) who found that, the annual mean concentrations of TPM at Shoubra El-Kheima were 762.2 μg/m^3 and 695.7 μg/m^3, respectively. While, this result is higher than that found by Khillare et al. (2004) in India and Al-Masri et al. (2006) in Syria.

The annual mean concentration of SPM reported in this study is similar to many Egyptian studies that found by Hassan (2000) Cairo city (399.7 ug/m^3), Ibrahim (2000) Greater Cairo (297-560 ug/m^3), Hassanein et al. (2001) Cairo city (397.0 ug/m^3), Hassan (2006) Greater Cairo (654 ug/m^3 during summer–769 ug/m^3 during winter), Ezoo (2006) Sadat city (384.5 ug/m^3), El-Mekawy (2007) Helwan city (438.5 ug/m^3) and El-Hashemy (2010) in El-Mansoura city (216.5 ug/m^3).

SPM Hospital Admissions Respiratory Disease at sites-1 (North Shoubra El-Kheima), site-2 (South Shoubra El-Kheima), site-3 (North Helwan) and site-4 (South Helwan) during study period (Table-4). It indicated that the risk of SPM increased as SPM increase. Table (4) shows that the assessment of respiratory hospitalizations was 3.7% (95% CI 3.5 - 3.8%) at site-1, 4.0% (95% CI 4.0 - 4.1) at site-2, 4.0% (95% CI 4.1%) at site-3 and 4.1% (95% CI 4.1–4.2%) per 10 μg/m3 increase of SPM. This values are higher than those measured in Tallinn, Estonia 1.14% (95% CI 0.62–1.67%), in Shanghai-China 0.23% (95% CI: −0.03%, 0.48%) and in northern China 0.036% (0.012–0.06%) (Wang and Mauzerall, 2006; Orru et al, 2009; Guo et al., 2009, 2010a, b and Chen et al., 2010b).

Several studies have examined the association between PM and respiratory hospital admissions. The respiratory hospital admission were estimated in different countries over the world: 2003 case in Malaysia, 1240 case in China, 8970 case in USA per 100000 people (USEPA, 1997; Chen et al., 2002; Afroz et al., 2003; Wang; Mauzerall, 2006 and Fattore et al, 2011).

Guo et al. (2009, 2010a, b) and Chen et al. (2010b) found that PM was significantly association with total respiratory hospitalization with RRs of 1.14 (95% CI: 1.01, 1.29). And it was stronger in the cool season (from November to April) than in the warm season (from May to October).

Table (5) reports a brief description of the locations of sampling points over the world, the obtained concentrations for particulate matter and the expected effects or risk results.

In conclusion, this study is the first attempts to applied the Air-Q 2.2.3 model and the approach proposed by the WHO to provide quantitative data on the impact of particulate matter exposure on the health of people living in Shoubra EL-Kheima and Helwan areas in Greater Cairo, Egypt. The results data are recommends using of these models for policy makers and regulations as it can be use for the local authorities to decide on the necessity of reclamation of the two sites and the level of priority of the intervention, with respect to situation of other polluted areas.

Table (4): SPM Hospital Admissions Respiratory Disease at sites in Shoubra El-Kheima and Helwan areas during study period

Site		RR	SPM Conc. (ug/m^3)	No. of excess cases per 100000 people	95% CI	No. of Hospitalization
Shoubra El-Kheima	North (site-1)	1.189	250-299	1541.3	3.5 - 3.8	634135.2
			300-349	2875.8		
			350-399	3451		
			>= 400	3667.6		
		1.138	250-299	1461.8		
			300-349	2727.6		
			350-399	3273.1		
			>= 400	3478.6		
		1.241	250-299	1591.8		
			300-349	2970.1		
			350-399	3564.1		
			>= 400	3787.8		
	South (site-2)	1.274	250-299	57.1	4.0 – 4.1	684044.3
			350-399	905.7		
			>= 400	3956.3		
		1.38	250-299	58.4		
			350-399	926.3		
			>= 400	4046.5		
		1.496	250-299	59.2		
			350-399	939.3		
			>= 400	4103.1		
Helwan	North (site-3)	1.29	350-399	1027.5	4.1	687168.8
			>= 400	3974.4		
		1.405	350-399	1050		
			>= 400	4061.7		
		1.53	350-399	1063.9		
			>= 400	4115.5		
	South (site-4)	1.377	>= 400	4052.9	4.1 – 4.2	700740.6
		1.532	>= 400	4121.9		
		1.704	>= 400	4164		

Table (5): Quantitative relationship of short-term exposure to daily mortality

Location	24h exposure (ug/m^3)		Results	Reference
	TSP	PM_{10}		
Salt lake city, UK, USA	-	47 - 297	Significant increase in mortality (50 – 100 ug/m^3) – 7.5%	Pope, 1992
Salt lake city, UK, USA	-	47 - 297	No Significant increase overall; some increase in the elderly	Lyon, 1995
Philadelphia, PA, USA	<380	-	7% increase in total mortality per 100 ug/m^3 Increase in TSP; weather, season in models	Schwartz, 1992
Philadelphia, PA, USA	<380	-	No Significant increase	Li, 1995
Steubenville, OH, USA	<36->209	-	4% increase in total mortality per 100 ug/m^3 Increase in TSP; weather, season in models	Schwartz, 1992
Athens	-	78 – 306	Significant 3.4%increase in mortality (50 – 100 ug/m^3)	Touloumi, 1994
San Jose and other CA areas, USA	-	<150	0.12%increase in mortality per increase of 10 ug/m^3 PM10	Fairley, 1990
Los Angeles and other CA areas, USA	-	>100	1.1%increase in mortality per increase of 10 ug/m^3 PM10	Shumway, 1988
Los Angeles and other CA areas	>200	>100	No increase in total or cause-specific mortality	Abbey, 1995
Los Angeles and other CA areas	-	58 – 177	No increase in total or cause-specific mortality	Kinney, 1995
St. Louis, MO, USA	-	28 – 97	Significant 8%increase in total mortality (50 – 100 ug/m^3)	Dockery, 1992
Kingston, TN, USA	-	30 – 67	No significant increase in mortality	Schwartz, 1993
Birmingham, AL, USA	-	48 – 163	Significant 5%increase in total mortality (50 – 100 ug/m^3)	Schwartz, 1993
Toronto, Canada	-	40 – 96	Significant 2.5%increase in total mortality (50 – 100 ug/m^3)	Ozkaynak, 1994
Chicago, IL, USA	-	38 – 128	Significant 2.5%increase in total mortality (50 – 100 ug/m^3)	Ito, 1995
Chicago, IL, USA	-	37 – 365	No significant increase in total mortality	Styer, 1995
Santiago, Chile	-	115 – 367	Significant 2.6 - 7%increase in total mortality (50 – 100 ug/m^3)	Ostro, 1996
Beijing, China	108 – 350	-	Significant doubling of respiratory disease mostly related to TSP	Xu, 1994

Corresponding author
A.A. Shakour
Air Pollution Department, Environment research Division, National Research Center, Cairo, Egypt.
ateffathy2006@yahoo.com

References

Abbey, D.E.; Lebowitz, M.D.; Mills, P.K.; Petersen, F.F.; Beeson, W.L.; Burchette, R.J. (1995). Long-term ambient concentrations of particulates and oxidants and development of chronic disease in a cohort of nonsmoking California residents. Inhal. Toxicol. 7: 19–34.

Abdel Hameed, A.A. (2003). Airborne particulate matter and its viable fraction during severe weather conditions in Cairo, Egypt. Journal of Scientific Research of Trakya University Series B, Natural and Applied Sciences, Turkey 4(1): 1-8.

Afroz, R.; Hassan, M.N. and Ibrahim, N.A. (2003). Review of air pollution and health impacts in Malaysia. Environmental Research, 92:71–77.

Al–Masri, M. S.; Al-Kharfan, K. and Al-Shamali, K. (2006): Speciation of Pb, Cu and Zn determined by sequential extraction for identification of air pollution sources in Syria. Atmos. Environ. 40: 753 – 761.

CAPMAS (Central Agency for Public Mobilization And Statistics) (2011): Annual report, Egypt, http://www.capmas.gov.eg.

Chan, L.Y. and Kwok, W.S. (2000). Vertical dispersion of suspended particulates in urban area of Hong Kong. Atmos. Environ., 34 (26): 4403 – 4412.

Chen, C.; Chen, D.; Green, C. and Wu, C. (2002). Benefits of expanded use of natural gas for pollutant reduction and health improvement in Shanghai. The Sino sphere Journal 5 (2), 58–64.

Chen, R.; Pan, G.; Kan, H.; Tan, J.; Song, W. and Wu, Z. (2010b). Ambient air pollution and daily mortality in Anshan, China: a time-stratified case-crossover analysis. Sci. Total Environ. 408:6086–91.

Chow, J.C.; Watson, J.G.; Fujita E.M.; Lu, Z.Q.; Lawson, D.R. and Chow, J.C.; Watson, J.G.; Lowenthal, D.H.; Soloman, P.A.; Magliano, K.L.; Ziman, S.D. and Richards L.W. (1993). PM10 and PM2.5 Compositions in California's San Joaquin Valley. Aerosol Sci. Tech., 18: 105 – 128.

Chow, W.H.; Mclaughlin, J.J.; Menck, H.R. And Mack, T.M. (1994). Risk factors for extrahepatic bile duct cancers: Los

Angeles County, California (USA). Cancer Causes Control, 5, 267-272.

Dockery, E.W.; Schwartz, J. and Spengler, J.D. (1992). Air pollution and daily mortality: associations with particulates and acid aerosols. Environ. Res. 59: 362–373.

EEAA (Egyptian Environmental Affairs Agency) (1994). Environmental Protection, Law No 4, Egyptian Environmental Affairs Agency, Maadi, Cairo, Egypt.

EEAA (Egyptian Environmental Affairs Agency) (2008). Egypt State of Environment Report -2008, Egyptian Environmental Affairs Agency, Maadi, Cairo, Egypt.

El-Dars, F.M.S.; Mohamed, A.M.F. and Aly, h.A.T. (2004). Monitoring ambient sulfur dioxide levels at some residential environments in the Greater Cairo urban region – Egypt, Environmental Monitoring and Assessment 95: 269–286.

El-Hashemy, M.A.A. (2010): Impact of the Air Pollutants on Metals Corrosion, Ph.D. Thesis, Chemistry Dept., Faculty of Science, Ain Shams University, Egypt.

El-Mekawy, A.M. (2007): Exposure assessment due to environmental pollution of Helwan city, thesis, Zoology Dept., faculty of science, Helwan University, Egypt.

EPA (Environmental Protection Agency) (2010). Air Quality Criteria pollutants. http://www.epa.gov/air/criteria.html.

EU (European Community) (1992). European Community Desk book. Washington, D.C.: Environmental Law Institute.

Ezoo, A.A. (2006). Effect of industrial emissions on the environment at Sadat city in Egypt. M.Sc. Thesis, Chemistry Department, Faculty of Science, Cairo University.

Fairley, D. (1990). The relationship of daily mortality to suspended particulates in Santa Clara County, 1980–1986. Environ. Health Pers. 89: 159–168.

Fattore, E.; Paiano, V.; Borgini, A.; Tittarelli, A.; Bertoldi, M.; Crosignani, P. and Fanelli, R. (2011). Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. Environmental Research.

Guo, Y.; Jia, Y.; Pan, X.; Liu, L. and Wichmann, H.E. (2009). The association between fine particulate air pollution and hospital emergency room visits for cardiovascular diseases in Beijing, China. Sci. Total Environ. 407:4826–30.

Guo, Y.; Tong, S.; Li, S.; Barnett, A.G.; Yu, W. Zhang, Y. (2010a). Gaseous air pollution and emergency hospital visits for hypertension in Beijing, China: a time-stratified case cross over study. Environ. Health, 9:57.

Guo, Y.; Tong, S.; Zhang, Y.; Barnett, A.G.; Jia, Y. and Pan, X. (2010b). The relationship between particulate air pollution and emergency hospital visits for hypertension in Beijing, China. Sci. Total Environ. 408:4446–50.

Han, X. and Naher, L.P. (2006). A review of traffic-related air pollution exposure assessment studies in the developing world. Environ. Intern. 32 : 106 – 120.

Hassan, S.K.M. (2000). A Study on Indoor Air Quality in Greater Cairo. M.Sc. Thesis, Chemistry Department, Faculty of Science, Cairo University, Egypt.

Hassan, S.K.M. (2006). Atmospheric Polycyclic Aromatic Hydrocarbons and Some Heavy Metals in Suspended Particulate Matter in Urban, Industrial and Residential Areas in Greater Cairo. Ph.D. Thesis, Chemistry Department, Faculty of Science, Cairo University, Egypt.

Hassanien, M.A. and Harvath, A. (1995): Central European Journal of Occupational and Environmental Medicine, 1:1, pp. 68-77.

Hassanien, M.A. (2001): Assessment of Human Exposure to Atmospheric Trace Metals in a Residential Area of Cairo, Egypt, CEJOEM 2001, Vol.7. Nos.3-4.:253-262.

Hindy, K.T.; Farag, S.A. and El-Taieb, N.M. (1990): Monthly and seasonal trends of total suspended particulate matter and smoke concentration in industrial and residential areas in Cairo, Atmospheric Environment. Part B. Urban Atmosphere, Volume 24, Issue 2, 1990, Pages 343-353.

Ibrahim, Y.H. (1992): Industrial pollutants and their impact on plant. M.Sc. Thesis, Faculty of science, Cairo University, Egypt.

Ibrahim, Y.H. (2000): Air pollution in the industrial area north of Cairo with special reference to its effects on plants. PhD. Thesis, Department of Botany, Faculty of Science, Cairo University, Egypt.

Ito, K.; Kinney, P. and Thurston, G.D. (1995). Variations in PM_{10} concentrations within two metropolitan areas and their implications to health effects analyses. Inhal. Toxicol. 7: 735–745.

Khillare, P.S.; Balachandran, S. and Meena, B.R. (2004): Spatial and temporal variation of heavy metals in atmospheric aerosol of Delhi. Environ. Monit. Assess. 90: 1 – 21.

Khoder, M.I. (1997). Assessment of Some Air Pollutants in Cairo and their Role in Atmospheric Photochemistry. Ph.D Thesis, Chemistry Department, Faculty of Science, Ain Shams University, Egypt.

Kinney, P.L.; Ito, K. and Thurston, G.D. (1995). A sensitivity analysis of mortality/PM_{10} associations in Los Angeles. Inhal. Toxicol. 7: 59–69.

Kleinman, M.T.; Pasternack, B.S.; Eisenbud, M.E. and Kneip, T.J. (1980). Identifying and estimating the relative importance of sources of airborne particulates. Environ. Sci. Tech. 14 (1): 62 – 65.

Li, Y. and Roth, H.D. (1995). Daily mortality analysis by using different regression models in Philadelphia County, 1973–1990. Inhal. Toxicol. 7: 45–58.

Lyon, J.L.; Mori, M. and Gao, R. (1995). Is there a causal association between excess mortality and exposure to PM_{10} air pollution? Additional analyses by location, year, season and cause of death. Inhal. Toxicol. 7(5): 603–614.

Ministry Of Health (2009). Curative Sector, General Directorate For Chest Diseases report.

Orru, H.; Teinemaa, E.; Lai, T.; Tamm, T.;l Kaasik, M.; Kimmel, V.; Kangur, K.; Merisalu, E. and Forsberg, B. (2009). Health impact assessment of particulate pollution in Tallinn using fine spatial resolution and modeling techniques. Environmental Health, 8:7 doi:10.1186/1476-069X-8-7.

Ostro, B.; Sanchez, J.M.; Aranda, C. and Eskeland, G.S. (1996). Air pollution and mortality: results of a study of Santiago, Chile. J. Exp. Anal. Environ. Epidemiol. 6: 97–114.

Ozkaynak, H.; Xue, J.; Severance, P.; Burnett, R. and Raizenne, M. (1994). Associations between daily mortality, ozone, and particulate air pollution in Toronto, Canada. Presented at: Colloquim on particulate air pollution and human mortality and morbidity, Irvine, CA. University of

California at Irvine, Air Pollution Health Effects Laboratory, Report No. 94-02.

Paoletti, L.; Falchi, M.; Viviano, G.; Ziemacki, G.; Batisti, D. and Pisani, D. (1989). Features of airborne breathable particulate in a remote rural and in an urban area. J. Water, Air and Soil Pollution, 43 (1-2): 48 – 85.

Pope, C.A.; Schwartz, J. and Ransom, M.R. (1992). Daily mortality and PM_{10} pollution in Utah Valley. Arch. Environ. Health, 47: 211–217.

PRIDE (Project in Development and the Environment) (1994). Comparing Environmental Health Risks in Cairo, Egypt, USAID/Egypt project number: 398–0365; Vols. 1–3.

Saleh, I.A. (2002). Air quality and effects of air pollutants on materials of different structures in Cairo atmosphere. Ph.D Thesis, Department, Faculty of Science, Ain Shams University, Egypt.

Schwartz, J. and Dockery, D.W. (1992). Particulate air pollution and daily mortality in Steubenville, Ohio. Am. J. Epidemiol. 1992; 135: 12–19.

Schwartz, J.; Slater, D.; Larson, T.V.; Pierson, W.E. and Koenig, J.Q. (1993). Particulate air pollution and hospital emergency room visits for asthma in Seattle. Am. Rev. Respir. Dis. 147: 826–831.

Shakour, A.A.; Hassanien, M.A. and El-Taieb, N.M. (2001). Trend of air pollution by particulate matter in the industrialized area of Shoubra El-Kheima, Cairo. The Egyptian Journal of Community Medicine, vol. 19, no.4.

Shakour, A.A. and Ashraf, S.Z. (1996). Effect of weather condition on the chemical constituent of total suspended particulate. Metrology and Integrated Development Conference. Cairo: 285-296.

Shumway, R.H.; Azari, A.S. and Pawitan, Y. (1988). Modeling mortality fluctuations in Los Angeles as functions of pollution and weather effects. Environ. Res. 45: 224–242.

Soliman, A.A. and Borai, E.H. (2001). Monitoring and statistical evaluation of heavy metals in airborne particulates in Cairo, Egypt. J. of Chrom. A, 920: 261 – 269.

Styer, P.; McMillan, N.; Gao, F.; Davis, J. and Sacks, J. (1995). The effect of airborne particulate matter on daily death counts. Environ. Health Pers. 103(5): 490–497.

Touloumi, G.; Pocock, S.J.; Katsouyanni, K. and Trichopoulos, D. (1994). Short-term effects of air pollution on daily mortality in Athens: a time-series analysis. Int. J. Epidemiol. 23: 1–11.

USEPA (US Environmental Protection Agency) (1990). Review of the National Ambient Air Quality Standard for Particulate Matter: Assessment of Scientific and Technical Information. Research Triangle Park, N.C.

USEPA (US Environmental Protection Agency) (1995a). National Air Pollutant Emission Trends, 1990-1994.

USEPA (United States Environmental Protection Agency) (1997). The benefits and costs of the Clean Air Act, 1970-1990. EPA-410-R-97-002, United States Environmental Protection Agency Office of Air and Radiation Policy. http://www.epa.gov/airprogm/oar/sect812/.

Wang, X. and Mauzerall, D.L. (2006). Evaluating impacts of air pollution in China on public health: Implications for future air pollution and energy policies. Atmospheric Environment 40:1706–1721.

WHO/UNEP (World Heath Organization/United Nations Environment Programme) (1992). Urban Air Pollution in the Megacities of the World, Oxford, Blackwell.

WHO (World Health Organization) (1979). Sulfur Oxides and Suspended Particulate Matter. Environmental Health Criteria 8. Geneva.

WHO (World Health Organization) (1987). Air Quality Guidelines for Europe. Copenhagen: WHO Regional Office for Europe.

WHO (World Heath Organization) (2004). Protection of the human environment, assessing the environmental burden of disease at national and local levels, Geneva.

Xu, X.; Gao, J.; Dockery, D.W. and Chen, Y. (1994). Air pollution and daily mortality in residential areas of Beijing, China. Arch. Environ. Health, 49(4): 216–222.

9/13/2011