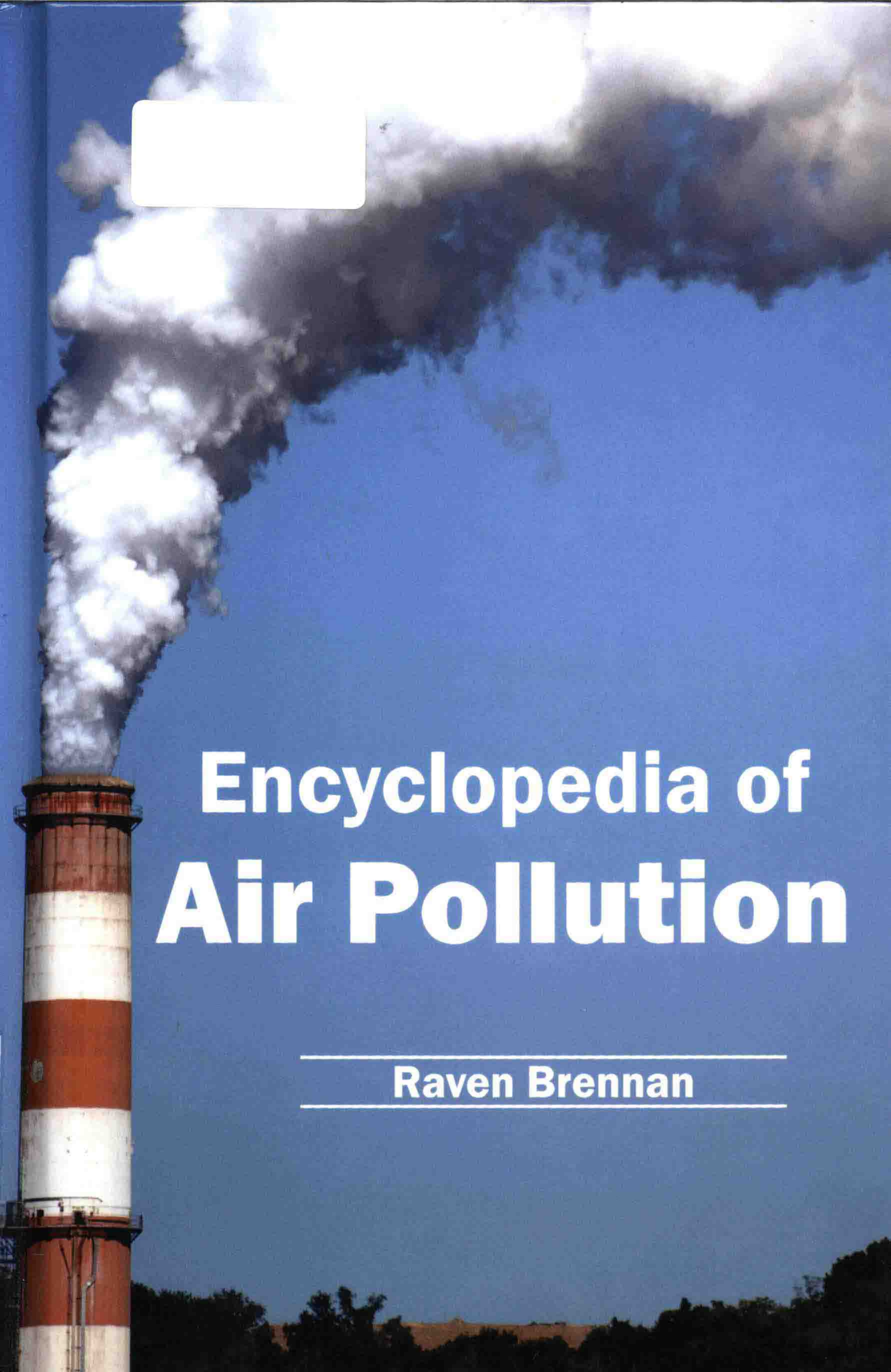

Encyclopedia of Air Pollution

Raven Brennan

Encyclopedia of Air Pollution

Edited by **Raven Brennan**

Callisto Reference

New York

Published by Callisto Reference,
106 Park Avenue, Suite 200,
New York, NY 10016, USA
www.callistoreference.com

Encyclopedia of Air Pollution
Edited by Raven Brennan

International Standard Book Number: 978-1-63239-174-2 (Hardback)

Printed in the United States of America.

Encyclopedia of Air Pollution

Preface

This book has been a concerted effort by a group of academicians, researchers and scientists, who have contributed their research works for the realization of the book. This book has materialized in the wake of emerging advancements and innovations in this field. Therefore, the need of the hour was to compile all the required researches and disseminate the knowledge to a broad spectrum of people comprising of students, researchers and specialists of the field.

The crucial problem of air pollution has always been of great concern. It has been a major environmental problem and an issue of global interest for many years. High concentrations of air pollutants due to several anthropogenic actions influence the quality of the air. This book will help you in filling the gaps existing in the fields of air quality monitoring, modelling, exposure, health and control, and will be of great help to graduates, professionals and researchers. It presents a variety of monitoring techniques of air pollutants, their predictions and control. It also includes case studies explaining the exposure and health implications of air pollutants on human beings in various countries around the world.

At the end of the preface, I would like to thank the authors for their brilliant chapters and the publisher for guiding us all-through the making of the book till its final stage. Also, I would like to thank my family for providing the support and encouragement throughout my academic career and research projects.

Editor

Contents

1

Air Pollution in Mega Cities: A Case Study of Istanbul

Selahattin Incecik and Ulaş Im
[1]*Istanbul Technical University, Department of Meteorology, Maslak, Istanbul*
[2]*University of Crete Department of Chemistry, Environmental Chemical Processes Laboratory (ECPL) Voutes, Heraklion, Crete*
[1]*Turkey*
[2]*Greece*

1. Introduction

A megacity is defined by the United Nations as a metropolitan area with a total population of more than 10 million people. This chapter provides a brief introduction to the air pollution in megacities worldwide. This is an extensive topic and brings together recent comprehensive reviews from particular megacities. We have here highlighted the air quality in megacities that are of particular relevance to health effects.

The main objective of this chapter is to enhance our understanding of the polluted atmosphere in megacities, with respect to the emission characteristics, climate, population and specific meteorological conditions that are leading to episodes. Therefore, the chapter will provide state-of-the-art reviews of air pollution sources and air quality in some selected megacities, particularly Beijing, Cairo, Delhi and Istanbul. Furthermore, a detailed analysis of emission sources, air quality, mesoscale atmospheric systems and local meteorology leading to air pollution episodes in Istanbul will be extensively presented.

The world population is expected to rise by 2.3 billion, passing from 6.8 billion to 9.1 billion in between 2009 and 2050 (UN Report, 2010). Additionally, population living in urban areas is projected to gain 2.9 billion from 3.4 to 6.3 billion in this period. However, during the industrial revolution years, only about 10% of the total population lived in the cities. As an example, in 1820, which is the beginning times of the United States (US) transformation from rural to urban, the great majority of the population lived in rural areas of US (about 96%) (Kim, 2007). Today, according to UN Report the world population in urban areas has reached to 50.5%. In other words, half of the world's population are concentrated in the cities. However, distribution of urban population in the world is not evenly. A significant diversity in the urbanization levels can be seen in different regions of the world. About 75% of the inhabitants of the more developed regions lived in urban areas in 2010, whereas this ratio was 45% in the less developed regions. It is expected that urbanization will continue to rise in both more developed and less developed regions by 2050 with about 86% and 69%, respectively. These developments have created new physical, social and economic processes in the cities. For example, uncontrolled urban sprawl has leaded the rising of environmental problems due to high traffic volume, irregular industry, and low quality housing, etc. Massive urbanization in the cities due to the better job opportunities and challenges in the urban areas began first in Europe and then in other regions of the world, particularly in Asia. At this point, urbanization levels have led to a new classification and a concept- megacity- which is usually defined as a metropolitan area with a total population in excess of 10 million inhabitants. Megacities are highly diverse in the world, spanning from Paris (France), Los Angeles, New York City (USA) in developed countries to Delhi (India), Dhaka (Bengladesh) and Lagos (Nigeria) in developing countries. In today's developing countries, megacities exhibit the highest levels of pollution and therefore, in the studies of the anthropogenic impact on atmospheric composition, have become of primary importance, particularly those having high traffic volumes, industrial activities and domestic heating emissions.

The United Nations Environment Programme Urban Environment (UNEP-UE) unit expressed that more than 1 billion people are exposed to outdoor air pollution annually and the urban air pollution is linked to up to 1 million premature deaths and 1 million pre-native deaths each year. Additionally, UNEP presented the cost of urban air pollution with approximately 2% of GDP in developed countries and 5% in developing countries, respectively. In addition, the UNEP/Global Environmental Monitoring System (GEMS) reported that rapid industrialization, burgeoning cities, and greater dependency on fossil fuels have caused increasing production of harmful pollutants, creating significant health problems in most urban cities. The serious air quality problems, specifically inverse health effects, have been experienced in megacities of both developing and developed countries. due to the exposure to high concentrations of particular matter (PM), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), hydrocarbons (HC) and sulfur dioxide (SO_2) depending on country's technology level. Especially, exposure to eleveted levels of particular matter and surface ozone causes loss of life-expectancy, acute and chronic respiratory and cardiovascular effects. Furthermore, damage to the ecosystem biodiversity by excess nitrogen nutrient is an important consequence of pollution.

In the beginning of the 2011, The European Commusion released a paper about the current policy efforts and the expected results to maintain a hard line against countries that are yet to comply with EU air quality legistlation limiting fine particulate matter ($PM_{2.5}$) concentrations. WHO (2009) concluded that megacities have faced particularly health impact by transportation, governance, water and sanitation, safety, food security, water and sanitation, emergency preparedness, and environmental issues. Furthermore, Baklanov (2011) recently shared results of the EU MEGAPOLI project (Megacities: Emissions, Impact on Air Quality and Climate, and Improved Tools for Mitigation and Assessment), which focuses on the multiple spatial and temporal scales from street to global levels and vice versa. The project addresses megacities with air quality and climate having complex effects on each other. Another EU-funded project CityZen (Megacities: Zoom for the Environment) also focused on impact of megacities on their environment and climate and vice versa from local to global aspects using long-term ground and satellite observations as well as regional and global modeling.

2. Megacities and air quality

As of 2011, there are 26 megacities in the world such as Tokyo, Guangzhou, Seoul, Delhi, Mumbai, Mexico City, New York City, Sao Paulo, Istanbul and other sixteen , eight of which exceeds 20 million. Fig. 1 presents the population in megacities world-wide with their continents. The four of the megacities are located at the South Hemisphere. Fifteen megacities are located at the tropical and humids-subtropical regions. This characteristic is important due to the growing evidence of the climate-health relationships posing increasing health risks under future projections of climate change and that the warming trend over recent decades has already contributed to increased morbidity and mortality in many regions of the world (Patz, et al., 2005). A total of 14 megacities, corresponding to more than of 50% of the total megacities, are located at the Asia continent, particularly in south and east parts. In this very dynamic region of the world, there are significant increases in industrialization and urbanization enhanced the urban population growth and economic development. This also leads to drastic increases in energy consumption and pollutant emissions in these regions. As an example, China is a rapid developing country with an urban population rate that increased from 19.6% to 46% within the last three decades.

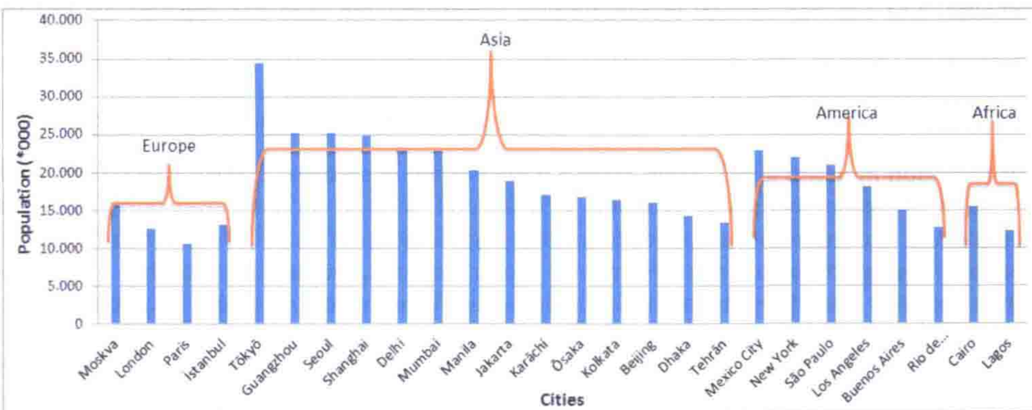

Fig. 1. Populations of the megacities with respect to their continents.

According to "China's blue paper", urban population ratio will reach 65% by 2030 in China. In recent years, a remarkable increase in the number of studies for air quality in China has been conducted (Kai et al., 2007; Chan and Yao, 2008; Wu et al., 2008; Fang et al., 2009; Wang et al, 2010;Zhu et al., 2011; Jahn et al., 2011). As an example, Chan and Yao (2008) extensively discussed the urbanization and air quality characteristics in Beijing, Shanghai and cities in Pearl River Delta (PRD) which is the mainland of China's leading commercial and manufacturing region covering Guangzhou, Shenzhen and Hong Kong. They noticed that in spite of the much attention to reduce emissions through effective control measures, particulate pollution is still severe in megacities of China. Among them, Guangzhou, which is the fourth largest city in China, is the main manufacturing hub of the PRD. In this city, the major industries are located in this industrial zone. In an earlier study by Kai et al. (2007) Air Pollution Index (API) values of Guangzhou were compared with the values of Shanghai and Beijing. The API for Guangzhou is higher than those of Beijing and Shanghai indicating that TSP was the prominent pollutant accounting for 62% of the major share in Guangzhou

(Zhou et al., 2007). In order to improve the air quality in Guangzhou, several new strategic efforts have been planned and established in industry and transportation sectors. Examples of the new control measures in transportation are; the metro line, which was opened in 1997, bus rapid transit system, hybrid buses, and design of low-emission zones in busy traffic areas. In a very recent study, Zhu et al. (2011) investigated the transport pathways and potential sources of PM_{10} in Beijing.

On the contrary to the classical air pollution events in megacities that are above mentioned, Los Angeles, USA (34°03′N; 118°15′W) which is in a large basin surrounded by the Pacific Ocean to the west and several mountain peaks to the east and south, and having a population of over 18 million, remains the most ozone-polluted region in the country. The Los Angeles region, which has a subtropical Mediterranean climate, enjoys plenty of sunshine throughout the year. The frequent sunny days and low rainfall contribute to ozone formation and accumulation as well as high levels of fine particles and dust in Los Angeles. The city area has the highest levels of ozone nationwide, violating federal health standards with an average of 137 days a year. The population growth, dependence on private motor vehicles, and adverse natural meteorological conditions can lead the episodic air quality levels in this area.

2.1 The general characteristics of air pollution and emission sources in megacities

Air pollution in urban areas comes from a wide variety of sources. The sources responsable for high emission loads are grouped into several sectors such as transport, domestic commercial and industrial activities for anthropogenic sources and NMVOCs from biogenic sources. Transport sector includes mainly motor vehicles, trains, aircraft, ship and boats while industry and domestic activities include fuel combustion including wood, coal, and gas for heating and production. Besides, biogenic (natural) emissions include NO_x and VOC emissions from vegetation and soils (Guenther et al., 2006). Today, urban air quality is a major concern throughout the world. Molina (2002) indicated that the quality of the air we breathe is fundamental to the quality of life for the growing millions of people living in the world's burgeoning megacities and deteriorating urban air quality threatens the public health. Furthermore, airborne emissions from major urban and industrial areas influence both air quality and climate change. This challenge is particularly acute in the developing world where the rapid growth of megacities is producing atmospheric pollution of unprecedented severity and extent. Mage et al. (1996) reviewed the difficulties in finding solutions to the air pollution in the megacities. Baldasano et al. (2003) examined the air quality for the principal cities in developed and developing countries. According to the study, the current state of air quality worldwide indicates that SO_2 maintains a downward tendency throughout the world, with the exception of some Central American and Asian cities, whereas NO_2 maintains levels very close to the WHO guideline value in many cities. However, in certain cities such as Kiev, Beijing and Guangzhou, the figures are approximately three times higher than the WHO guideline value. In the Asian databases consulted, only Japan showed really low figures. Surface ozone levels presents average values that exceed the selected guideline values in all of the analysis by regions, income level and number of inhabitants, demonstrating that this is a global problem with consequences for rich and poor countries, large and medium cities and all the regions.

Gurjar et al. (2008) examined the emissions and air quality pertaining to the megacities. He and his colleagues ranked megacities in terms of their trace gas and particle emissions and ambient air quality, based on the newly proposed multi-pollutant index (MPI) which considers the combined level of the three criterion pollutants (TSP, SO_2 and NO_2) in view of the World Health Organization (WHO) guidelines for air quality. Simulations of the export of air pollution from megacities to downwind locations via long-range transport (LRT) have shown different transport patterns depending on the megacity location: in the tropics export is occurring mostly via the free troposphere, whereas at mid and high latitudes it occurs within the lowest troposphere (Lawrence et al., 2007). Butler & Lawrence (2009) simulated small impacts of megacities on the oxidizing capacity of the atmosphere and larger on reactive nitrogen species on global scale. They also pointed out the need of parameterization of the sub-grid effects of megacities. Butler et al. (2008) analyzed different emission inventories and found substantial differences in emission's geographical distribution within countries even if the country total emissions are the same. They also reported large differences in the contribution of various sectors to the total emissions from each city.

Table 1 presents the megacities with their location, climate type, major emissions and critical air quality parameters. As seen in Table 1, there is a significant geographical variation in domestic heating emissions. Specifically, particulate matter is a major problem in almost all of Asian and Latin cities. In all of the megacities, emissions from the motor vehicles are a major contributor of harmful pollutants such as nitrogen oxides and particulate matter. The most important source for the classical pollutants such as particular matter, sulfur dioxide, nitrogen oxides, carbon monoxide, and volatile organic compounds are combustion of fossil fuels.

3. Megacity of Beijing

Beijing (39°54'N; 116°23'E), the capital of China, has completed its third decade of economic development known as the Economic Reform and Open Policy starting in 1978, and is a rapidly developing megacity with a 16 million population (Fang et al., 2009). As it's the capital city, Beijing continues to experience substantial growth in population, economic activity, business, travel and tourism. The city is situated at the northern tip of the roughly triangular North China Plain, which opens to the south and east of the city. Mountains to the north, northwest and west shield the city and northern China's agricultural areas from the desert steppes. Beijing has been experiencing severe anthropogenic air pollution problems since 1980s due to the significant energy consumption depending on developments of the city. Furthermore, natural sources have a significant impact on the city environment such as dust transport from the northern parts of the city. This leads to polluted smog covering the city as a thick blanket under specific meteorological conditions.

3.1 Climate

Beijing is in a warm temperate zone and has a typical monsoon-influenced humid continental climate with four distinct seasons. It is usually characterized by hot and humid summers and dry winters.

Megacity	Lat ; Lon	Popul. (million)	Area (km^2)	Climate Type	Major Emission Source(s)	Critical Air Quality Parameters
Beijing (CN)	39°54'N; 116°23'E	16.0	16,800	Monsoon-influenced humid continental	Domestic heating, traffic,industry, dust,biomass burning	PM_{10}, $PM_{2.5}$, NO_2, O_3
Buenos Aires (ARG)	34°36'S; 58°22'W	15.0	4,758	Humid subtropical	Motor vehicles, industry	CO, NO_x
Cairo (EGY)	30°3'N; 31°13'E	17.2	86,370	Hot and dry desert	Industry, motor vehicles,dust transport	PM_{10}, $PM_{2.5}$
Delhi (IND)	28°36'N; 77°13'E	23.0	1,483	Humid subtropical	Motor vehicles, industry	PM_{10}, $PM_{2.5}$, NO_2
Dhaka (BNG)	23°42'N; 90°22'E	14.6	360	Hot, wet and humid tropical	Industry,road dust, open burning	PM_{10}, $PM_{2.5}$, SO_2
Guangzhou (CN)	23°08'N; 113°16'E	12.7	7,434	Humid subtropical	Industry, motor vehicles, power generation	PM_{10}, NO_2
Istanbul (TUR)	41°01'N; 28°58'E	13.2	5343	Mediterranean	Motor vehicles, industry	PM_{10}, CO, NO_x
Jakarta (IN)	6°12'S; 106°48'E	18.0	740	Hot and humid tropical wet and dry	Motor vehicles, Industry	PM_{10}, NO_2, O_3,CO
Karachi (PK)	24°51'N; 67°0'E	17.0	3,527	Arid	Industry, Motor vehicles	PM_{10} (TSP), CO, NO_2
Kolkata (IND)	22°34'N; 88°22'E	15.6	1,480	Tropical wet and dry	Domestic, Motor vehicles, Waste	PM_{10},NO_2
Lagos (NGR)	6° 25′N;3° 23′E	12.0	999	Tropical savanna	Industry, Motor vehicles,	SO_2, PM_{10}, NO_2
London (UK)	51°30'N; 0°7'W	12,6	1572	temperate	Mostly traffic	PM_{10}, NO_2
Los Angeles (USA)	34°3'N;118°15'W	17.7	1302	Subtropical-Mediterranean	Motor vehicles, petroleum rafinery, power generation	O_3, NO_x
Manila (PHP)	14°35'N;120°58'E	20.8	638	Tropical savanna/ tropical monsoon climate	Power generation, industry motor vehicles	PM_{10}, SO_2

Megacity	Lat ; Lon	Popul. (million)	Area (km^2)	Climate Type	Major Emission Source(s)	Critical Air Quality Parameters
Mexico City (MEX)	19°26'N; 99°08'W	21,1	1,485	Subtropical high land	Motor vehicles	PM_{10}, O_3,BC (soot), NO_2
Moscow (RUS)	55°45'N 37°37'E	16.0	1,081	Humid continental	Motor vehicles, Industry, Power generation	SO_2, PM_{10}, NO_2, CO
Mumbai (IND)	18°58'N; 72°49'E	23.0	603	Tropical wet and dry	Industry, Motor vehicles, Power plants, Domestic, land fill open burning, road dust	PM_{10}, PAH, hazardeous chemicals
New York City (USA)	40°43'N;74°00'W	19.0	1,214	Humid subtropical	Motor vehicles	$PM_{2.5}$, O_3
Osaka (JPN)	34°41'N; 135°30'E	16.6	222	Humid subtropical	Motor vehicles	PM_{10}, $PM_{2.5}$, NO_2, O_3
Paris (F)	48° 51' N;02° 21' E	11.8	14,518	Western European oceanic climate	Motor vehicles	PM_{10}, $PM_{2.5}$, O_3, NO_2
Rio de Janeiro (BR)	22°54'S; 43°11'W	14.4	4,557	Tropical savanna climate / tropical monsoon	Motor vehicles	PM_{10}, NO2
Sao Paulo (BR)	23°33'S;46°38'W	22.0	7,944	Monsoon-influenced humid subtropical climate	Industry, Motor vehicles	PM_{10}, BC,O_3
Seoul (KR)	37°34'N;126°58'E	25.0	605	Humid subtropical / humid continental climate	Motor vehicles	PM_{10}, NO_2, O_3
Shanghai (CN)	31°12'N; 121°30'E	24.7	6,340	Humid subtropical	Industry, Motor vehicles, Dust transport	PM_{10}, NO_2
Tehran (IRN)	35°41'N ;51°25'E	13.4	1,274	Semiarid continental	Industry, Motor vehicles	CO, NO_2, PM_{10}

Table 1. List of megacities and their characteristics.

3.2 Air pollution sources

The major anthropogenic emission sources in Beijing are domestic heating, traffic and industry. Coal dominated energy structure is also one of the major causes of air pollution in Beijing (Hao, et al., 2007). As an example to the total emissions from energy production sector of 16.0 GWh/y, Hao et al. (2007) calculated a 102,497 t/y of SO_2, 60,567 t/y of NO_x and 11,633 t/y of PM_{10}. Domestic heating in Beijing usually starts in mid-November and ends in the following March and it is the major source for SO_2 in the winter season (Chan and Yao, 2008; Hao et al., 2005). Furthermore, industrial emissions emitted from Shijingshan region, located west of Beijing, are significant sources of particulate matter in Beijing. Beijing experiences a serious urban sprawl which has been claimed to be a major factor leading to the need for long-distance travel, congestion in the city centre and private vehicle usage problem (Zhao, et al., 2010; Deng & Huang, 2004). The number of cars in Beijing has grown rapidly and reached to 4.76 million vehicles in 2011, up from 1.5 million in 2000 and 2.6 million in 2005, according to official statistics provided by the municipal transportation authorities. Particulate matter emitted from motor vehicles and re-suspension of road dust are also likely contributors to PM_{10} pollution in the city (Song et al., 2006). Last but not least, natural dust originating from the erosion of deserts in northern and northwestern China results in seasonal dust_storms that plague the city.

3.3 Air quality in Beijing

Beijing is party to the Standard Ambient Air Quality Standards (GB 3095-1996), which sets limits for SO_2, CO, PM_{10} and nitrogen dioxide (NO_2). The Chinese air quality standards set separate limits for different types of areas such as Class I, II and III based on physical characteristics of the region such as natural conservation areas and special industrial areas. Beijing is designated as a Class II area, which applies to residential, mixed commercial/ residential, cultural, industrial, and rural areas.

TSP and SO_2 have been the major pollutants in China for a long time due to the fossil fuel burning from power plants, industry and domestic heating. However, in recent years, the Chinese Government have planned to reveal a major environmental plan to help managing air pollution and is expected to include efforts to reduce pollution through new regulations and strategies including taxes and investments in this field. As an example, energy-related measures include fuel substitution and flue gas desulfurization facilities, which were built at the coal fired power plants, control measures such as energy efficiency and fuel use and dust control improvements (Hao et al. 2007). Initiatives have also been implemented in Beijing. The use of natural gas has been increased four-fold from 2000 as a result of efforts made to replace coal fired boilers and family stoves to use natural gas, and coal heating with electrical heating. As a result of these initiatives, from 1990 to 1999, the annual average TSP concentration in 100 major cities decreased by 30% to 256 μg/m3 and it remained almost constant from 1999 to 2003 (Sinton et al., 2004), despite an overall decrease of 30% in total energy consumption from 1997 to 2002. Fang et al. (2009) examined the air quality management in China and the changing air quality levels with their reasons. The results of the new strategies in Beijing are seen in Fig.2. In 1998, Beijing started its phased intensive control program to fight air pollution. PM_{10} concentrations increased by around 10% from 2003 to 2006 because of the increase in coal-fired boiler emissions, construction activities and dust storms (United Nations Environment Program, 2007). The annual PM_{10} concentrations in Beijing decreased from 162μg/m³ in 2006 to 141μg/m³ in 2007 despite an increase in energy consumption. The recent measurements of PM_{10} indicates lower levels such as 123μg/m³ in 2008; 120μg/m³ in 2009, respectively. One of the reasons of the high level of PM_{10} is residential coal-combustion in Beijing. SO_2 emissions from residential coal-combustion in Beijing were increased from 68,800 tons in 2003 to 85,100 tons in 2005. The expansion of the urban areas and the increase in SO_2 emissions led to increased particulate sulfate concentrations, which resulted in higher PM_{10} levels. However, SO_2 levels in the city are decreasing (Fang et al., 2009). Furthermore, Beijing experiences high PM_{10} pollution during spring dust storms. Zhu et al. (2011) showed that the typical wind speed of such dust storms is approximately 7 m/s or more, and the sand and dust sources are located about 1000-2000 km northwest of Beijing. According to Zhu et al. (2011), dust storms can reach to Beijing within 3 days.

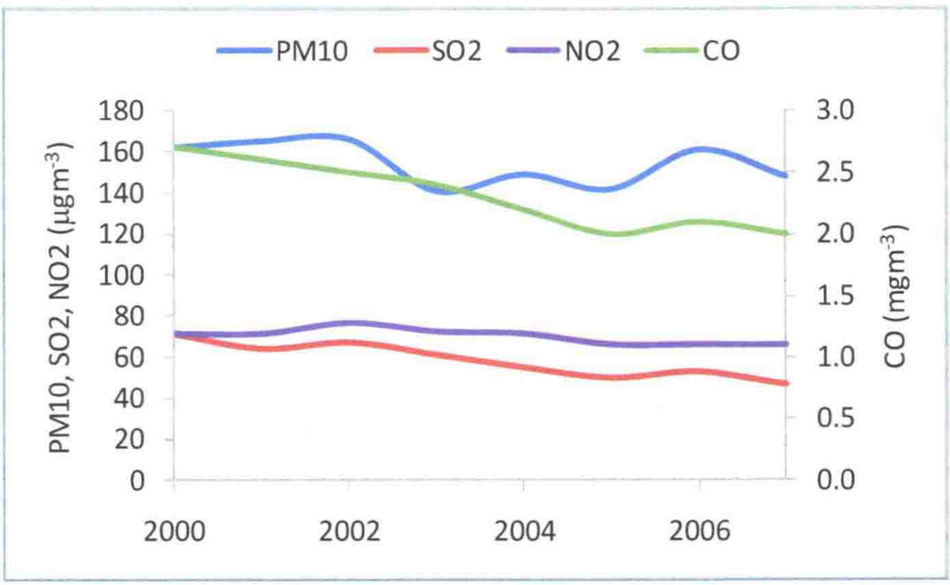

Fig. 2. Variations of annual-mean PM_{10}, SO_2, NO_2 (μgm-3) and CO (mgm-3) levels in Beijing (2000-2008) *Air quality standard for PM_{10} is 100 μg/m3 and WHO guideliness is 20μg/m³.

Recently, heavy industries have been gradually replaced by less polluting industries in Beijing. Besides, several possible activities are planned on major polluting industries such as the closure of cookery units at coke and chemical plants as well as closure of cement, lime and brick plants. The, transport sector is also a major contributor to Beijing's air quality. In this sector, stringent vehicle emission standards have been established. The Beijing municipal government will also implement traffic control measures such as the improvement of fuel quality to meet the new emission standards and to ease the city's traffic congestion.

4. Megacity of Cairo

Greater Cairo (30°3'N; 31°13'E), which is the capital of Egypt, is the largest city in Africa and located in northern Egypt, to the south of the delta in the Nile basin. The Greater Cairo consists of Cario, Giza and Kalubia, and has a population of about 17 million inhabitants. The city which about one-third of Egypt's population and 60% of its industry and is one of the world's most densely populated cities. Gurjar, (2009) and Decker et al., (2000) reported that Cairo's population is confined in 214 km^2 area making it the most densely populated megacity. The urbanization and industrialzation have increased very rapidly in Greater Cairo, particularly in the second half of the last century.

4.1 Climate

The climate in Cairo and along the Nile River Valley is characterized by a hot, dry desert climate. Wind storms can be frequent, bringing Saharan dust into the city during the spring. Abu-Allaban et al. (2002; 2007 and 2009) reported that wind speeds in wintertime is weaker than during summer, implying a lower ventilation of the area during winter that could favor pollutant accumulation in the vicinity of the sources. Additionally, Safar and Lebib (2010) indicated that the arid climate in the city causes a persistent high background PM level in the Cairo area.

4.2 Air pollutant emissions

The air pollution in Cairo is a matter of serious concern. The major emissions in the city come from industry and motor vehicles which cause high ambient concentrations of PM, SO_2, NO_x and CO. There are over 4.5 million cars on the streets of Cairo according to recent records. The relative contribution to particulate pollution from different economic activities is shown in Table 2. As seen in the table, the major contribution to the particulate load is urban solid waste burning by 30%. Transport and industry follows the solid waste by 26% and 23%, respectively. Kanakidou et al. (2011) summarized a comprehensive overview of the actual knowledge on the atmospheric pollutant sources, and the levels in the Eastern Mediterranean cities including Cairo. The annual sectoral distribution of pollutants are calculated for Cairo based on 2005 year as the reference year. Road transport and residential activities are important sources of PM and responsible for almost 35.9% and 53.4% of the PM_{10} emissions, respectively. Industrial activities have a major part for the SO_2 with 71.5% (Kanakidou et al., 2011). Furthermore, a typical black cloud appears over Cairo and rural regions of the Nile Delta in every fall due to biomass burning. It is found that this event is a major contributor to the local air quality. Molina and Molina (2004) explained the black cloud in Cairo during fall season based on the open burning of agricultural waste (mostly burning of rice harvest by farmers to clear fields for the next harvest in rural areas of Nile Delta). Additionally, traffic, industrial emissions and secondary aerosols was attributed to the black cloud events. Prasat et al. (2010) indicated the long range transport of dust at high altitudes (2.5-6 km) from Western Sahara and its deposition over the Nile Delta region. New evidence of the desert dust transported from Western Sahara to Nile Delta during black cloud season and its significance for regional aerosols have potential impact on the regional climate. Recently, the European Investment Bank approved a 90,000 EURO grant in order to investigate methods to reduce the burning of rice straw, which is thought to be one of the potential sources of these clouds (UN and League of Arap States Report, 2006). In addition to all, Cairo is the only city in Africa having a metro system (about 42 km length and carrying 60,000 passengers per hour in each direction).