DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

INVENTORY OF AIR POLLUTANT EMISSIONS FROM DOMESTIC HEATING IN RESIDENTIAL AREAS OF İZMİR

by

Deniz SARI

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İZMİR

INVENTORY OF AIR POLLUTANT EMISSIONS FROM DOMESTIC HEATING IN RESIDENTIAL AREAS OF İZMİR

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"INVENTORY OF AIR POLLUTANT EMISSIONS FROM DOMESTIC HEATING IN RESIDENTIAL AREAS OF IZMIR"** completed by **DENİZ SARI** under supervision of **PROF. DR. ABDURRAHMAN BAYRAM** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Hopefully this thesis will have useful implications for future work on.

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INVENTORY OF AIR POLLUTANT EMISSIONS FROM DOMESTIC HEATING IN RESIDENTIAL AREAS OF İZMİR

ABSTRACT

Air pollution in cities is a major environmental problem principally in the developing countries recently. Emission inventories are basic requirement to assess the human influence to the atmosphere. The aim of this study is to quantify the amount of domestic heating emissions in İzmir. For that purpose major air pollutants such as particulate matter (PM_{10}), sulfur dioxides (SO_2), nitrogen dioxides (NO_2), volatile organic compounds (VOC) and carbon monoxide (CO) together with greenhouse gases which are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) amounts were estimated by using USEPA, CORINAIR and IPCC emission factors for 2008-2009 winter season.

The results indicated that the highest emissions were released from Karabağlar and Konak where a greater proportion of households use coal for domestic heating. Three methods were used to estimate greenhouse gases and the results estimated by using IPCC's emission factors were higher than those calculated by using CORINAIR and USEPA's emission factors.

At the second part of the study, calculated emissions were modeled by using CALMET/CALPUFF dispersion modeling system and plotted in the form of air pollution maps by using geographical information system. Model results were tested with observed air quality data from seven monitoring stations for 2008-09 winter season. Comparison of average daily predicted and monitored concentrations was matched for particulate matter; but for the sülfür dioxide, predicted concentrations are lower than the monitored concentrations contrary to expectations.

Keywords: air pollution, air quality, greenhouse gases, emission inventory, air quality modeling, calpuff, geographical information systems

İZMİR'DE YERLEŞİM ALANLARINDA EVSEL ISINMADAN KAYNAKLANAN HAVA KİRLETİCİLERİN ENVANTERİ

ÖZ

Son yıllarda başta gelişmiş ülkelerde olmak üzere kentsel hava kirliliği temel çevre sorunlarından biri haline gelmiştir. Hava kalitesi seviyelerinin iyileştirilmesi için en temel gereksinim emisyon envanterleridir. Bu çalışmanın amacı İzmir'de evsel ısınmadan kaynaklanan hava kirleticilerin miktarlarının belirlenmesidir. Bu amaçla 2008-09 kış dönemi için başlıca hava kirleticilerden olan havada asılı partikül madde (PM_{10}), kükürt dioksit (SO_2), azot dioksit (NO_2), uçucu organik bileşikler (VOC) ve karbon monoksit (CO) ile karbon dioksit (CO_2), diazot monoksit (N_2O) ve metan (CH_4) gibi sera gazlarının miktarları USEPA, CORINAIR ve IPCC emisyon faktörleri kullanılarak hesaplanmıştır.

Hesaplanan emisyon sonuçlarında doğalgaz kullanımının daha yaygın olduğu yerleşim bölgelerinde emisyonların azaldığı, en yüksek emisyonların kömür kullanımının daha fazla olduğu Karabağlar ve Konak ilçelerinden kaynaklandığı belirlenmiştir. Sera gazı emisyonları hesaplanırken üç farklı metot karşılaştırılmış ve IPCC emisyon faktörleri ile belirlenen emisyonların CORINAIR ve USEPA' ya ait faktörlerle hesaplananlardan yüksek olduğu anlaşılmıştır.

Bu çalışmanın ikinci bölümünde, hesaplanan emisyonlar CALMET/CALPUFF dispersiyon model sistemi ile hava kalitesi tahminlerine dönüştürülmüş ve coğrafi bilgi sistemleri kullanılarak kirlilik haritaları çizilmiştir. Model sonuçları kentteki yedi hava kalitesi izleme istasyonuna ait 2008-2009 kış dönemi verileri ile test edilmiştir. Karşılaştırılan ortalama yıllık tahmini ve ölçüm değerleri arasında partikül maddeler için bir uyum gözlenirken; kükürt dioksit için karşılaştırmasında tahmin edilen değerler beklenenin aksine ölçülen değerlerden düşük çıkmıştır.

Anahtar Sözcükler: hava kirliliği, hava kalitesi, sera gazları, emisyon envanteri, hava kalitesi modellemesi, calpuff, coğrafik bilgi sistemleri

CONTENTS

Page

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Urban areas are broadening each day in today's society as economic growth leads to higher income and better living conditions. However, urban development also causes an increase in energy demand which produces air pollution. Population growth in the metropolitans, however, is a major reason for the air quality problems and change in land use (Mayer, 1999). Since the world's population and industrialization level with new technologies are growing day by day, more energy is needed. Most cities of the world which uses mostly fossil fuels uses either directly or converted (through the use of fossil fuels) electricity for urban/industrial energy needs. For instance their use for domestic heating is one of the main sources of air pollution in the atmosphere. Fossil fuel sources have detrimental impacts on human and environmental health.

The air pollution in cities especially show raises with the opening of winter season. The major reasons of air pollution caused by heating during the winter are using low quality coal and wrong application of incineration techniques. Fuel consumption for domestic heating is dependent to dimension of house, heating methods, isolation, size of family and economic reasons (Douthitt, 1989). The amounts and types of fuel change by incomes of households or where they live (Masera & Navia, 1997). Meteorological parameters such as temperature, wind speed and direction, humudity affect to the rates of fuel consumption (Marufu, Ludwig, Andre & Levieveld, 1999).

It is obvious that the composition of the atmosphere is affected by anthropogenic sources. Air pollutants are mainly consist of gases like SO_2, NO_x, O_3, atmospheric particles, dusts smaller than 10 microns in particle size, hydrocarbons, and waste gases from different emission sources (Karaöz, 2001). Some of these effects can be regional but the majority of them are on global scale like the global warming due to the increase of greenhouse gases emissions, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the halocarbons. These greenhouse gases (GHGs) are together with other trace gases such as sulfur dioxide (SO_2), nitrogen oxides (NO_x) or volatile organic carbons (VOC_s) and aerosols in the atmosphere. Gases and aerosols may undergo chemical reactions and physico-chemical transformations in the troposphere and due to these chemical reactions, gaseous species are turned into other gases or into aerosol particles, and they drop from the atmosphere with dry or wet deposition processes depending on the reactivity of the gas or the aerosol and its atmospheric residence time. The use of coal for heating purposes can cause to increase smog and mist in cities since those smoke particles act as condensation nuclei for fog and end up with high sulfur dioxide concentrations (Jıménez, Climent-Font & Anton, 2002).

Emission inventories are necessary for understanding the impact of human activity on air quality in the large urban areas (Markakis, Poupkou, Melas, Tzoumaka & Petrakakis, 2009). They play a considerable role not only in policy development regarding emission regulations but also in analysis of air quality. Policy makers have to efficiently estimate the amount of the spatial and temporal density of emission sources at the best resolution possible in order to plan reduction strategies for air pollution control. These inventories are fundamental and necessary tools for assessing the human and environmental risks that is from anthropogenic pollutant sources (Kim et. al., 2009). Air pollution must be controlled by preparing a clean air plan applicable at urban and regional scales in such a large region with a multiplicity of economic activities and high density of population (Müezzinoğlu, Elbir & Bayram, 2003). In winter the air pollution levels in cities can increase due to domestic heating (Jaber & Probert, 2001).

Mathematical and numerical techniques are used in air quality modeling (AQM) to simulate the dispersion of air pollutants. A model requires two types of data inputs which are sources' information and meteorological data (İm, 2000). The pollutant's transport and dispersion depends on its chemical and physical transformations and removal process. Many air quality dispersion models have been developed as computer programs by various organizations and they are commonly used for different air quality determination studies all over the world (Scire, Strimaitis & Yamartino, 2000a). California Puff (CALPUFF) is a guideline model recommended for regulatory use in the U.S. and many other international regulatory agencies. CALPUFF is used in a wide variety of applications by registered users in over 105 countries throughout the world.

Air pollution has become an actual problem in İzmir due to rapid urbanisation and increase in the pollutive sources. Air pollution problem occurs under the unsuitable meteorological conditions, which increases in winter due to the usage of inequal coal for domestic heating.

This study focused on the estimation of domestic heating emissions and air quality modeling of the emissions in İzmir in 2008-2009's winter season (01.11.2008-31.03.2009). A local emission inventory in the city center of İzmir was prepared to estimate emissions of main pollutants (SO_2, CO, PM, NO_x and VOC) as well as greenhouse gases (CO_2, CH_4 and N_2O). At the next stage of the study, calculated emissions were modeled in the study area using the CALMET/CALPUFF dispersion modeling system. The system contains three main programs: the meteorological model CALMET, the dispersion model CALPUFF, and the post processing model CALPOST. The meteorological data were obtained from four meteorological stations. Surface data were taken from İzmir, Aliağa, Seferihisar, and Manisa Meteorological Stations and upper air data was taken from İzmir Meteorological Station. The meteorological data were then processed by CALMET Meteorological Model, and wind fields which are used as input for CALPUFF were produced. The emission data required by CALPUFF were obtained from prepared emission inventory. At the last step of the study model results were compared with monitoring data from seven air quality stations (Alsancak, Karşıyaka, Şirinyer, Bornova, Çiğli, Gaziemir and Güzelyalı) obtained in İzmir during 2008-2009 winter season. Geographical information system (GIS) was used to show the results for both emission inventory and air quality predictions.

CHAPTER TWO
LITERATURE REVIEW

2.1 Emission Inventory

Emission means that the gases and particles which are released into atmosphere from anthropogenic sources (factories, power plants, motor vehicles, airplanes) and natural sources (trees, vegetation).

The emission estimations can be done in three different ways: the direct measurement method, material balance method and emission factors method. Generally emissions are measured over a period of time and the number of such periods for emission estimation. But emissions measurements always cannot be achieved or aren't useful for quantifying. In this situation emission factors (EF) can be used for emission estimation from literature. Emission factors are the coefficients which are prepared as a conclusion of different emission measurement ended before, and they identify the amount of pollutants given to the atmosphere per a unit of activity by a specific source. The general equation for emissions estimation is given in Equation 1.

$E = A \times EF \times (1 - ER/100)$ **(Equation 1)**

E = emissions

A = activity rate

EF = emission factor

ER = overall emission reduction efficiency, %

Three types of emission factors can be used to prepare emission inventory.

a) Mass of emissions per mass of fuel burned (g / kg dry fuel or g/m^3 gas-liquid fuel)
b) Mass of emissions per unit of heat delivered (g/mJ)
c) Mass of emissions per unit time of activity (g/hr)

Emission sources are generally categorized as point, line and area sources covering industrial, vehicular and domestic sources, correspondingly. The amounts of pollutants, emitted from these sources, are estimated by using fuel consumption data and suitable emission factors (Elbir, 2003). Generally European CORINAIR database (CITEPA, 1992), US Environmental Protection Agency emission factors catalogue (USEPA, 1998a) and Intergovernmental Panel on Climate Change Guidelines (IPCC) are widely used emission factors catalogues (Lin et.al., 2005; Zeydan, 2008; Müezzinoğlu et al., 2000). European emission factors were insufficient to indicate the industrial subcategories so usually USEPA emission factors are chosen (Elbir & Müezzinoğlu, 2004).

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories were produced at the call of the United Nations Framework Convention on Climate Change (UNFCCC) to update the Revised 1996 Guidelines and associated good practice guidance which provide internationally agreed methodologies planned for use by countries to estimate greenhouse gas inventories to report to the UNFCCC.

An emission inventory, which is a set of information on sources and emissions of air pollutants in a specified area, may encompass both man-made and natural emissions. Generally data is categorized in some detail by type of pollutant, source type or class and source position. Emissions estimates or projections are regularly made for specific time periods. Air pollution emissions inventory is a data collection and processing system which consist of information on anthropogenic or natural air pollution sources and their emissions. Emissions inventories identify the sources of air pollution and quantify the emissions of them. Dependable emission inventory is a primary requirement for a qualified air quality management system. An emissions inventory system supports pollution assessment activities by planning, collecting, screening, storing, and presenting emissions data in a systematic and practical method. In addition, it supplies a database for meaning of future emission scenarios or of recommended air pollution control regulations (Weber, 1982). There are generally four steps which can be followed to prepare an emission inventory.

Planning

At the beginning of the inventory, the aim and target of study must be determined. Then, a specific area should be chosen and the pollutants with emission sources should be decided. All the steps of the emission inventory should be included in the work plan which is very important for studing systematically and solving the possible problems easily.

Data Collecting

When collecting data about air pollution sources which are major and small industrial facilities, residential areas, transportation and natural events; all causes of emissions must be recognized correctly. Within the above mentioned emitter categories, different procedures of data collection, which are using emissions factors, questionnaire forms and performing source testing and/or other special studies, may be applied or integrated.

Data Filtering

After collecting data in an emissions inventory system, its verification and its auditing procedures are certainly necessary. These data are judged according to the quality manually or by computers. This step can be use directly after all steps which are data collection, data storage, or with data summaries, in manual or computerized form. Then, the collected data should be arranged and evaluated to use to estimate emission.

Data Storage and Reporting

To storage data, which is the important step in an emissions inventory whose a systematic collection of a large amount of detailed data, is essential to have a system that allows effective processing, storage, and bringing back of the data. The main aim of an emissions inventory system is to provide the users with suitable and timely information. To achieve this, the system must be intended by user supplies and then identifying the data needed to provides this information the retrieval and summary capability necessary to produce desired data in a timely and useful mode. A manually-based emission inventory has only limited potential of providing the user with summaries and various retrieval scenarios. A computerized emission inventory system, on the other hand, allows a multitude of summaries and retrievals. Data can retrieved from a system according to different basic preparations which are source category, pollutants, specific geographical region. In addition, the results of emission inventory should be expressed clearly with the help of tables and graphics also.

Knowledge of the types of pollutants and their emission rates, which determine the level of pollution with the meteorological conditions and topographical factors, is primary to the study and control of air pollution. So emission inventory plays an important role when setting up air pollution control strategies or planning any growth, mainly in developed industrial areas or residential areas. An emission inventory is necessary as input to air quality models.

An emission inventory should have the following features; clearness, which is described as to be easy for understanding and for validating the calculations with results; constancy, which means that the time series can be comparable within the countries; comparability, which provides the international comparison of the data; wholeness, which shows that all pertinent sources and sinks are integrated in the emission inventory; accuracy, which provides quality assurance and management for the calculation process (Wirth & Theloke, 2006).

OECD Control of Major Air Pollutants (MAP) Project, the DGXI Inventory, the CORINE Programme and subsequent work by the European Environment Agency Task Force, the Co-Operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP), the IPCC/OECD Greenhouse Gas Emissions Programme are some important emission inventory projects depending on the sources of the developed countries (EMEP, 2003; Ağaçayak, 2007).

Recent Emission Inventory Studies

An emission inventory study made the case of the Aegean Region “Afyon, Aydın, Denizli, İzmir, Manisa, Muğla” (Müezzinoğlu et al., 2000). The highest emissions were calculated in Uşak. In the framework of another study done later, the clean air plan for the province of İzmir had been prepared (Müezzinoğlu et al., 2001). The existing air quality study first evaluated the province, and then prepared a detailed emission inventory modeling work has been done, pollutant sources and pollutant distribution maps were drawn and measures to improve air quality and recommendations had been revealed.

In 2000, approximately 7 million tons of particulate matter, 3.5 million tons of SO_2, 0.8 million tons of NO_x, 0.5 million tons of VOC’s and 1.8 million tons of CO released into the atmosphere in Turkey. 10–15 ratios of these emissions were sources from study area of Müezzinoğlu et al. research project in 1998 where a 60×80 km^2 area around the city of İzmir was focused on (Müezzinoğlu, Elbir & Bayram, 1998).

Elbir and colleagues prepared air pollutant emission inventory for domestic heating of Aegean region in 2001 (Elbir, Müezzinoğlu, Bayram, Seyfioğlu & Demircioğlu, 2001). According to this study, Aydın had the highest PM emission with 491000 tons/year. Afyon released the most SO_x emission (427000 tons/year) into the air. The maximum NMVOC and CO concentrations were calculated in Manisa as 152000 tons/year and 190000 tons/year, respectively. The emissions from domestic heating were 38433 tons PM, 8200 tons SO_x, 887 tons NO_x, 1216 tons NMVOC and 1517 tons CO per a year. In addition the highest NO_x emission was in İzmir owing to using natural gas.

Çetin studied estimated emissions of NOx from residential areas in Kocaeli in 2006. The study showed that total amounts of 574245 tons of lignite, 237101 tons of wood, 61756 tons of natural gas, 11452 tons of light fuel oil and 1.153 tons of LPG were used in residential buildings for domestic heating in the city. According to calculations, Gebze was the highest contributor to the total NO_X emission rate with

934 tons/year NO_X. The NO_X emission rates of Izmit Central, Derince, Körfez, Gölcük, Kandıra and Karamürsel were estimated 437, 231, 126, 117, 85 and 79 tons per a year, respectively (Çetin, 2006).

Özden, Döğeroğlu and Kara (2008) showed that domestic heating was dependable for SO_2, PM and CO pollution but NOx and VOC pollution originate from traffic in Eskişehir. However industry was the less importance for air pollution especially in the city center. With using natural gas for residential heating and industrial productions there had been a significant reduce in SO_2 from 200-250 $\mu g/m^3$ to under 50 $\mu g/m^3$ and in PM from 140-150 $\mu g/m^3$ to under 40 µg/m3. In 2004 average SO_2 and PM concentration values of the center of Eskişehir were 51 and 38 $\mu g/m^3$, respectively (Özden, Döğeroğlu & Kara, 2008).

Kecebaş and colleagues studied on the emissions from geothermal energy and natural gas used in the residential areas in the center of Afyon (Kecebaş, Gedik & Kayfeci, 2010). Their results showed that the local emissions of SO_2 and PM associated with fuel combustion had been reduced annually by 1700 tons/year and 421 tons/year for geothermal energy and 0.2 tons/year and 3.8 tons/year for natural gas, correspondingly. According to this study, using geothermal and natural gas for domestic heating was specified to prevent the release of SO_2 and PM emissions in huge quantities.

National governments that are parties to the UNFCCC and/or to the Kyoto Protocol are required to submit annual inventories of all anthropogenic greenhouse gas emissions from sources and removals from sinks. The Kyoto Protocol comprises additional requirements for national inventory systems, inventory reporting, and annual inventory review for determining compliance with Articles 5 and 8 of the Protocol.

The amount of greenhouse gases from vehicles was calculated in Lebanon in 1997 by using Intergovermental Panel on Climate Change (IPCC) methodology. The authors prepared two different scenarios for the reduction of emissions: the new vehicles technology and new transporting plans. It was explained that according to emission scenarios, the renewal of technologies in automotive showed no effect because of a noticeable improvement of travel demand in coming years (El-Fadel & Bou-Zeid, 1999).

Zeydan (2008) prepared an emission inventory of GHGs, which come from domestic heating, traffic and energy sector, in Zonguldak. The consumption in households with stove 3.37 tons coal and with central heating 4.30 tons coal in a year was determined according to questionnaire's results. 1703.1 tons/year SO_2, 624.9 tons/year NO_x, 686.7 tons/year NMVOC, 343.4 tons/year CH_4, 18885 tons/year CO, 2.84×10^5 tons/year CO_2, 2.7 tons/year N_2O and 425.8 tons/yıl PM_{10} were calculated by using USEPA emission factor. Further 3.048×10^5 tons/year CO_2, 966.71 tons/year CH_4 and 4.83 tons/year N_2O were estimated by IPCC greenhouse gas emission factors (Zeydan, 2008).

2.2 Air Quality Modeling and GIS

In the last years, with the increase in migration, majority of humankind has been transformed into urban dwellers. This situation has brought a huge number of problems, including air pollution. (Jiménez & Baldasano, 2002). Nowadays developed countries are awake to air pollution and work seriously to get better air quality. So they prepare clean air plans, scheme air quality regulations, monitor continuously air quality in urban and industrial areas and support to people for using of cleaner fuels such as natural gas. Air Quality Management (AQM) in cities is identified universal like a vital part of environmental management. These days AQM is used for monitoring and modeling almost on-line to decide the number of people affected by air pollution, and to evaluate actions to prevent dangerous situations (Kimmel & Kaasik, 2003). Fuel consumption and hence changes in air quality are determined with emission invetories and air quality modeling (Ocak & Ertürk, 2007).

The significance of emission inventories in air quality modelling had been indicated by many researchers (Russell & Dennis, 2000; Hanna et al., 2001; Zoras, Triantafyllou & Evagelopoulos, 2006; Poupkou et al., 2008a). A precondition for compiling accurate emission estimates is to bring together detailed and updated data (Passant, 2003). Moreover, inventories used in modeling studies must gather the model input necessities, namely the spatiotemporal resolution and chemical speciation, according to the model setup (Borge, Lumbreras & Rodriguez, 2007). In order to obtain that, modern tools such as GIS techniques can be executed. The latter tools which are increasingly been used for environmental modeling studies and air pollution analysis, provide an integrated system for quantification of emissions and spatial data analysis (Brodie, 1999; Symeonidis, Ziomas & Proyou, 2003; Symeonidis et al., 2008). The compilation of spatially and temporally resolved emission inventories can efficiently provide the demanding input fields of cell-based air quality models (Markakis, Poupkou, Melas, Tzoumaka & Petrakakis, 2009).

A model is a simplified picture of reality. It doesn't contain all the features of the real system but contains the features of interest for the management issue or scientific problem which can be solved by its use. Models are widely used to make predictions and/or to identify the best solutions for the management of unique environmental problems (Bluett et.al., 2004).

An atmospheric dispersion model is a tool for:

- mathematical simulation of the physics and chemistry guiding the transport, dispersion and transformation of air pollutants in the atmosphere
- estimating air pollution concentrations which give information about the emissions and nature of the atmosphere.

Following information are necessary for modeling:

- emission rate of air pollutant
- characteristics of the emission source
- topography of the study area
- meteorology of the study area
- ambient or background concentrations of air pollutants

Modeling results can also be used for:

- determining compliance of emissions with air quality guidelines, criteria and standards
- planning new plants
- deciding suitable stack heights
- controlling existing emissions
- making plans for ambient air monitoring networks
- identifying the main contributors to existing air pollution problems
- appraising policy and mitigation strategies like as the effect of emission standards
- estimating pollution episodes
- assessing and managing the risks of rare events (e.g. accidental hazardous substance releases)
- forecating the influence of geophysical factors such as topography and land use on dispersion
- running numerical laboratories for scientific research including experiments such as following accidental hazardous substance releases and involving foot-and-mouth disease
- saving cost and time over monitoring because of modeling costs are lower than monitoring costs and a simulation of long periods may only take a few weeks to assess.

Many dispersion models to estimate pollutant transport from emission sources using mathematical equations have been improved. These are:

a) Gaussian models
b) Lagrangian/Eulerian models
c) CFD models

Gaussian-plume models are generally used, well understood, easy to perform, and until more in recent times have received international confirmation. Now, from a regulatory point of view ease of appliance and consistency between applications is important. Also, the suppositions, errors and uncertainties of these models are generally well understood, though they still suffer from misuse. The Gaussian-plume formula is derived supposing ‘steady-state’ conditions which mean the formulae do not depend on time, even though they do represent an ensemble time average. The meteorological conditions are assumed to continue stable during the dispersion from source to receptor, which is effectively instantaneous. Emissions and meteorological conditions can be different from hour to hour but the model calculations in each hour are independent of others. Because of this mathematical derivation, it is regular to refer to Gaussian-plume models as steady-state dispersion models. The Gaussian-plume formula has the uniform wind speed in the denominator and therefore breaks down in calm conditions. It is common to indicate a minimum allowable wind speed which is generally 1 m/s, for the model (Bluett et.al., 2004).

Lagrangian puff atmospheric dispersal model is the one of the best model for simulating long-range transport for modeling the influence of gases and particulate matters on air quality.

CALPUFF which is a Langrangian model is recommended by the U.S. Environmental Protection Agency (USEPA) on studies for air quality modeling. It can produce and handle complex three-dimensional wind fields, and includes a complex terrain algorithm that is essential when the target domain is enlarged to include İzmir, as in the present study. In recent times, the integration of atmospheric emission inventories with geographical information systems (GIS) has been helpful for environmental researchers and environmental policy-makers to manage large amounts of emission information, analyzing spatial patterns within inventories, and improving the accuracy and resolution of emissions maps of study areas (Sivacoumar, Bhanarkar, Goyal, Gadkari, & Aggarwal, 2001; Elbir, 2003).

This modeling system contains three main components which are, CALMET, CALPUFF and CALPOST and a big set of preprocessing programs designed to interface the model to standard, regularly available meteorological and geophysical datasets (Scire, Strimaitis & Yamartino, 2000b).

CALMET, which aims to integrate with non-steady state CALPUFF modeling system for use in air quality modeling, is a state-of-the-science meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modeling domain, together with two-dimensional fields such as humidity, pressure, mixing height, surface characteristics and dispersion properties. CALMET reads from surface stations hourly wind speed, temperature, cloud cover, ceiling height, surface pressure, relative humidity. In addition precipitation type codes are essential to calculate wet removal. Even if temperature, cloud cover, ceiling height, surface pressure and relative humidity are not obtained from a surface station, the model replace this missing values by values at the closest station. The upper air data (radiosonde) are necessary for CALMET contains vertical profile of wind speed, wind direction, elevation, temperature and pressure. When wind speed, wind direction or tempature data is missing at an elevation, CALMET can interpolate to replace the missing data (İm, 2000).

CALPUFF, which is a multi-layer, multi-species non-steady-state puff dispersion model, is the one of modeling systems which is suggested by the Environmental Protection Agency (EPA) for simulating long-range transport and designed for the dispersion of gases and particles (USEPA, 1998b). The CALPUFF modeling system, united with a three-dimensional meteorological and land-use field, was developed for modeling the progress of the contaminants that cause to air pollution. The model can simulate the effects of temporally and spatially varying meteorological conditions on pollutant transport, removal of pollutants by dry and wet deposition processes, and transformation of pollutants through chemical reactions. CALPUFF is used to simulate incessant puffs of pollutants being emitted from a source into the ambient windflow which changes from hour to hour, the path of each puff takes changes to the new windflow direction. Puff diffusion is Gaussian and concentrations are established on the contributions of every puff while it passes over or near a receptor point (Scire, Strimaitis & Yamartino, 2000a). Data requirements of CALPUFF for each source according to the emission inventory are stack dimensions, output stack temperature, emission flow and velocity, etc. Besides, local meteorological data such as hourly surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure and relative humidity must be included. The output of the dispersion program is then calculated for each grid of the study area of substances from various pollutant sources.

CALPOST is used for postprocessing gridded concentrations that summarize the simulation gas, wet or dry flux results based on the hourly or average time of a series data contained in the CALPUFF output file.

ISCST3 model which is recommended from EPA was used for CO and NO_x concentration of Beijing in 2001 by Hao and colleagues (Hao, Wu, Fu, He & He, 2001). In 2004 Krishna et al. calculated the dispersion of SO_2 and NO_x with using the same model and compared with data of air quality stations (Krishna, Reddy, Reddy & Singh, 2004). They found likeness between stations' data and results of model. Kuhlwein et al. (2002) developed a new atmospheric dispersion model for modeling of different air pollutants with taking advantage of emission inventory of Ausburg locate in Germany (Kuhlwein, Wickert, Trukenmuller, Theloke & Friedrich, 2002). The new model was reported to be suitable after obtained outcomes were validated. Within air quality management in Fengan (China) different model approaches were investigated for air pollution modeling from area and point sources of city by Cheng and colleagues in 2006. According to the report, these approaches can be used to determine SO_2 and PM concentrations (Cheng, Li, Feng, Jin, & Hao, 2006).

In 2007 Ocak et al. investigated fuel consumption for domestic heating in winter season, the time of decrease in the air quality of cities in Turkey. They determined the relationship with meteorological parameters like temperature and wind velocity and fuel consumption. Fuel consumption and SO_2 emission levels were computed for meteorological conditions in different days at 2001-2002 winter seasons in Erzurum. ATDL model was used to estimate to SO_2 emission levels and results of model were compared Turkish Air Quality Protection Regulation and measured SO_2 concentration (Ocak & Ertürk, 2007).

GIS is used for capturing, storing, checking, analyzing, managing and displaying geographically referenced information. It is important to note, that GIS is not only used as a map viewer in the system, but more as an integrated tool to handle data from many sources. Once the model is calibrated, then different scenarios can be simulated in the decision support system developed. If no acceptable match is obtained between calibration and measurements, then it is necessary to return to the first step and check for errors in the estimation of the relevant parameters or perform the necessary corrections in the calculations (Clarke, 1986).

ArcMap, which is developed by ESRI, is used in GIS application usually due to its relative user friendliness and its global applies by local authorities and research institutes. This software is also well suited for developing dynamic environmental models. In this software, a particular present of the different shapes (industries, houses and roads) are called themes and can be selected in any order, e.g. localization of industries, emission patterns, etc. These themes can be selected or sorted according to the modeler criteria, importance the most applicable features on individual digital maps (Puliafito, Guevara, & Puliafito, 2003).

Jensen and colleagues (2001) produced a new model system whose name is AirGIS, for supporting to local authorities on air quality management of the big cities in Denmark. System was generated from combination of Operational Street Pollution Model and Denmark National Administrative Data which were about technical and cadastral electronic maps, buildings and population. Air pollutions levels were estimated in high temporal and spatial resolution whereby geographical information systems. Besides in this study the air pollution maps which showed exposure areas and air quality levels were formed (Jensen, Berkowicz, Hansen & Hertel, 2001).

An emission inventory which was integrated with GIS technology for estimating the spatial dispersion of stable and mobile sources in city of Beijing was developed.

CO and NO_x emissions came from anthropogenic sources as 1.4 million tons and 233000 tons. Furthermore he calculated that vehicles released into atmosphere 76.8% of total CO and 40.2% of total NO_x in 1995. In addition these gases were estimated with ISCST3 gauss dispersion model as 76.5% of total CO and 68.4% of total NO_x (Hao et.al., 2001).

Dalyan and İncecik (2002) searched for SO_2 concentrations and relationship with land use and population by GIS in heating seasons of Istanbul. They analyzed the average SO_2 concentrations according to temporal changes and noticed to discretion trend from 1992s to 2000s winter while using the data of five air quality monitoring stations (Dalyan & İncecik, 2002).

CHAPTER THREE

MATERIAL AND METHODS

3.1 Characteristics of the Study Area

The city of İzmir is situated at the west side of Turkey with longitude between 26.228° E and 28.459° E, and latitude between 37.833° N and 39.471° N, covering a total area of 11973 km^2. The city center of İzmir is located with longitude between 26.814° E and 27.372° E, and latitude between 38.287° N and 38.573° N, the third biggest urban agglomeration of Turkey and the acknowledged industrial and commercial capital of the Aegean Region. When this study started İzmir had nine districts but it has now twenty one districts, namely Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, Narlıdere, Urla, Bayındır, Foça, Kemalpaşa, Torbalı, Menemen, Seferihisar, Menderes, Selçuk and Aliağa. This area is called "Greater İzmir Metropolitan Municipality". So the boundaries of İzmir Metropolitan Munipacality in 2008, which can be named the city center of İzmir and includes Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak and Narlıdere, was accepted as our study area (Figure 3.1).

Figure 3.1 The map of study area in İzmir (The city center of İzmir).

İzmir is the centre of Aegean region of the western Anatolia. Climate is typically Mediterranean in the region; winters are warm and rainy, summers are hot and dry. Area is rough, with huge subsidence zones between a series of mountains laid at west-east axes and valleys are formed leading towards inner parts of Anatolia. In the low lands major rivers flow through rich agricultural lands. The city of İzmir, as many other big cities in Turkey, faces expanding urbanization, with economic growth, increase in air pollution, and loss of green or agricultural space (Müezzinoğlu, Elbir & Bayram, 2003).

With economical development, the population of İzmir increased from 153294 inhabitants in 1927 to 3276815 inhabitants in 2009. So this situation caused growing urbanization problems. These problems show raising deterioration of the air quality, a lack of infrastructure provision, land use quarrel and a growing number of slums.

Population growth rate from 2000 to 2009 in İzmir is 14.5% at the city center and is far above the average population growth rate in Turkey (TÜİK, 2009). Population density is 322 persons per km^2. The 91.1% of all population live in urban in İzmir. Therefore, the surroundings of the city are overpopulated thus creating a substantial risk to the forests and wealthy agricultural lands in the locality. Agriculture is still very essential although the cultivable land is narrowing down.

Leather, textile, cement, iron-steel, petrochemical and food are the main sectors of İzmir which has got a lot of diffirent industries facilities. Industrial emissions are the major sources of air pollution in the city (Elbir, 2002).

İzmir shows that the typical problems of an urban agglomeration. The burning of fossil fuels in industry, traffic and domestic heating activities, causes to air pollution in the city. The topographic situation in the basin and changes in airflows due to building evolvement have intensified the influences of emissions.

3.2 Residential Heating

The maximum temperatures during the winter months vary between 12 and 14 °C in İzmir. Although it's rare, snow can fall in the city in December, January and February staying for a period of hours rather than a whole day or more. So, in İzmir fewer fuels are consumed for domestic heating than the other cities.

Data of 2008 – 2009 winter season was provided by the authorities of İzmir Provincial Directorate of Environment and Forestry. According to the sales rates taken from the approved coal resellers, 1269653 tons of coal were sold in this winter season. Since study area covered 90% of İzmir population, 1142688 tons of coal was consumed in the city center of İzmir. Coal consumption per building was assumed around 1 tons. In addition, Consumed Coal Monitoring Project conducted by Yılmaz Kömür Ofisi, revealed results of coal consumption statistics of five residential areas through a survey. According to this survey, coal consumption of a house in Bornova is 1.074 tons, in Mithatpaşa is 0.800 tons, in Gaziemir is 1.347 tons, in Hatay is 1.450 tons, and in Alsancak is 0.916 tons (Kömür Yakım Takip Sistemi, 2011). To sum up, when surveys and consumption rates regarded, average coal consumption of a house in İzmir city center region could be accepted as 1 tons.

When 13% of the buildings in Turkey use electricity for domestic heating in 2003, consumption electricity in residential is also becoming widespread and nowadays increased exponentially (Ağaçayak, 2007). As in “Turkey’s Energy and Energy Efficiency Studies – Passing to the Greener Economy” Report suggested, which is prepared by Energy Efficiency Association in 2010, 25% of the buildings in Turkey uses electricity for air conditioning purposes while 72% of those is also use it for heating (Energy Efficiency Association, 2010). Within the scope of this study average values for Turkey were used for electricity use rates for domestic heating since those values unique to İzmir could not be attained. Roughly 206000 houses, which are nearly 18% of all houses in the city and reside within the borders of İzmir city center, uses electricity for domestic heating, as accepted so in this study and those are excluded in emission calculations.

In “İzmir Region Status Report” of 2008 prepared by İzmir Development Agency, the amount of houses using liquid fuel for central heating was 1404 in 2007 (İzmir Development Agency, 2008). When the number of houses which resides within the study area is regarded, the amount of liquid fuel usage (which stays extremely lower than 1% of all houses) was excluded from emission calculations, too.

Coal is the most common used fuel in İzmir with 74% of households using import or local coal on a typical winter’s night (Figure 3.2). While the majority of these use import coal although local coal is still being used in some districts, too. Wood isn’t the main fuel in the city center of İzmir, since it is used with coal. So the wood consumption wasn’t included to emission calculations. In addition the sums of monthly natural gas consumption per a district in 2008 and 2009 were obtained from İZMİRGAZ.

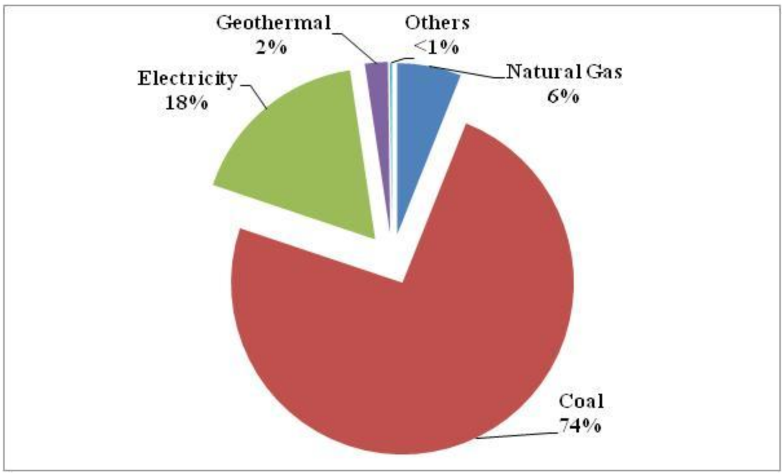


Figure 3.2 The distribution of energy consumption for residential heating in 2008-09 winter season.

3.3 Calculation of Emissions

Emission measurements sometimes cannot be achieved, in this situation emission factors can be used for emission estimation. In United States of America (USA) and Europe different sectoral emission factors are generated. In such studies, using Turkish emission factors which are based on operating situations in Turkey will be more reliable to determine results rather than the using of European or American factors. However this is not possible now because of the fact that Turkish emission factors have not prepared yet. Therefore, in this study EPA emission factors were chosen to calculate the emissions for SO_2, NO_2, PM_{10}, CO and VOC from domestic heating. The reason of choosing EPA emission factors in contrast to CORINAIR is that American EFs project the burning fuels which contain high intensity of ash and sulfur better than European EFs (Elbir & Müezzinoğlu, 2004). EPA, CORINAIR and IPCC emission factors were used for estimating emissions of CO_2, N_2O and CH_4.

Emissions were determined on the basis of households and the fuel consumptions of them in the city. Emissions owing to domestic heating are provided per km^2 and are based on the number buildings, type of heating system, fuel consumption and temperature variations expressed in terms of degree months. Evaluation of emissions from domestic heating includes the collection of data on home heating methods and fuel use, applied to as activity data, and the application of emissions factors to these data.

Emissions from house heating units were evaluated with the help of fuel use data apportioned all over district in the city center of İzmir. Quantities of fuels burned by the area sources per unit time were multiplied by suitable emission factors suiting the type of the fuels to give the total quantity of pollutant emissions over the area. The numbers of data of households were taken from GIS Department of İzmir Metropolitan Municipality. The Population data was obtained from Turkish Statistical Institute (TÜİK). Use of only two major fuel types; coal and natural gas were assumed for calculation of domestic heating emissions due to lack of information on wood and electricity. In addition geothermal energy isn’t used in calculations of emissions, because when it is used in a house there isn't any discharge to air. The domestic heating survey results explain variability in home heating methods across different districts. The amount of consumed coal is used as 1 tons imported coal per a year for each household in the city center of İzmir. In addition the sums of monthly natural gas consumption in 2008 and 2009 were obtained from İZMİRGAZ.

In addition, there are emissions from other public buildings for domestic heating such as hospitals, schools, etc. But the consumption data isn't available for many of these sources.

In this study, as a first step, the domestic heating source information on number of inhabitants, type of fuel use, fuel consumptions and population data are brought together. Subsequently, the emission factors are used to prepare an emission inventory, which will be computed and stored in databases of a GIS.

In Yalova generally used lignite coal and the 70% of this are export and the 30% local lignite. Export coal has lower sulfur fraction than locals (Irmak, 2005). But in this study all of the coal sold in İzmir is assumed to be import and the amounts of emissions were calculated according to this belief. Emissions for domestic heating in residential areas, for each contaminant and for each time period were calculated, established on Equation 2.

CE (tons/year) = EF (kg/tons) * FB (tons/year) / 1000(kg/tons) **(Equation 2)**

CE = pollutant emission (SO_2, NO_2 etc)

EF = emission factor

FB = fuel burned

Emissions of main pollutants from domestic heating activities were estimated by using the emission factors of USEPA given in Table 3.1 (Elbir et. al., 2009).

Table 3.1 Emission factors used to calculate residential heating emissions.

	Unit	**SO_2**	**NO_2**	**PM_{10}**	**CO**	**VOC**
Coal	g/kg	10.89	1.33	4.89	55.69	5.86
Natural Gas	g/m^3	0.02	1.85	0.02	1.01	0.27

At the moment, there are a lot of national and international guidelines for preparing greenhouse gases emission inventories on a more or less nation-wide level. In this study the USEPA and CORINAIR emission inventory guidelines to examplify classical air pollutants (SO_2, NO_2, etc.) with the IPCC Guidelines for National Greenhouse Gas Inventories were used. Emissions of greenhouse gases from domestic heating activities were estimated using the emission factors of USEPA, CORINAIR and IPCC given in Table 3.2 and compared the emission factors and greenhouse gas emissions. For calculating CO_2 emissions the percentage of carbon is assumed 57% in coal (Zeydan, 2008).

Table 3.2 Emission factors used to calculate greenhouse gas emissions.

		USEPA	**CORINAIR**	**IPCC(2006)**
Coal	**CO_2**	30.1 * %C (kg/tons)	94000 (g/GJ)	94600 (g/GJ)
	CH_4	2.27 (kg/tons)	450 (g/GJ)	300 (g/GJ)
	N_2O	0.018 (kg/tons)	1.4 (g/GJ)	1.5 (g/GJ)
Natural Gas	**CO_2**	1.922 (kg/m^3)	56000 (kg/TJ)	56100 (kg/TJ)
	CH_4	0.037 (g/m^3)	2.5 (kg/TJ)	5 (kg/TJ)
	N_2O	0.035 (g/m^3)	0.1 (kg/TJ)	0.1 (kg/TJ)

Low heating values of fuels were used while estimating the greenhouse gases emissions from domestic heating. The low heating value of coal was 6400 kcal/kg (Table 3.3) and the low heating value of natural gas was 8250 $kcal/m^3$ (İZMİRGAZ, 2007).

Table 3.3 The features of imported coal used for heating purposes in İzmir (İzmir Governor, 2010).

Low heating value(dry basis)	min. 6400 Kcal/kg (-200 Kcal/kg tolerance)
Total Sulfur Rate (dry basis)	max %0,9 (%+0,1 tolerance)
Total Humidity (orginal)	max %10 (+1 tolerance)
Ash (dry basis)	max %16 (+2 tolerance)
Volatile Matter (dry basis)	% 12-31 (+2 tolerance)
Dimension (*)	18-150 mm. (max ±% 10 tolerance)

3.4 Air Quality Modeling

In the second part of the study, calculated emissions were modeled to estimate air quality levels in the area by using the CALMET/CALPUFF dispersion modeling system. The system contains three main programs: the meteological model CALMET, the dispersion model CALPUFF, and the post processing model CALPOST. The meteorological data were obtained from four meteorological stations. Surface data were taken from İzmir, Aliağa, Seferihisar, and Manisa Meteorological Stations, and upper air data was taken from İzmir Meteorological Station. The meteorological data were then processed by CALMET Meteorological Model, and wind fields which are used as input for CALPUFF were produced. The emission data required by CALPUFF were obtained from prepared emission inventory. At the last step of the study model results were tested with monitoring data from seven air quality stations (Alsancak, Karşıyaka, Şirinyer, Bornova, Çiğli, Gaziemir and Güzelyalı) obtained in İzmir during the year 2008-2009. Geographical information system (GIS) was used to show the results for both emission inventory and air quality predictions.

3.4.1 Modeling Domain

In this study for calculating the air pollutant emissions from residential areas, a local emission inventory was prepared within an area of 50 km by 40 km centered at the study area in İzmir. For meteorological modeling, much wider study area (160 km x 120 km) was selected. The grid system with 4 km resolution was used for meteorological modeling domain. But for dispersion modeling domain the grid system was nested to 1 km resolution. The modeling domains are shown in Figure 3.3.

Figure 3.3 Meteorology and dispersion modeling domains.

3.4.2 Topographical Data

İzmir is placed in a basin bounded by a mountain range of approximately 1000–1500 m height with only the west end open to the Aegean Sea. The area of city is rough, with huge subsidence zones between a series of mountains laid at west-east axes and valleys are formed leading towards inner parts of Anatolia. In the low lands major rivers flow through rich agricultural lands (Müezzinoğlu, Elbir & Bayram, 2003). Yamanlar and Manisa (Spil) Mountains at the north, Kemalpaşa (Nif) at the east and Seferihisar (Karabelen) mountains at the south surround the city. The altitudes of these mountains are 1000 m, 1400 m, 1530 m and 980 m, respectively (Dinçer, 2001).

The topographical data of İzmir was obtained from “Shuttle Radar Topographic Mission (SRTM) 90m Digital Elevation Data” is produced by National Aeronautics and Space Administration (NASA) for CALPUFF (Consortium for Spatial Information [CGIAR-CSI]). N37E026, N37E027, N38E026 and N38E027 topographic maps were used to obtain terrain data of the study area (Figure 3.4).

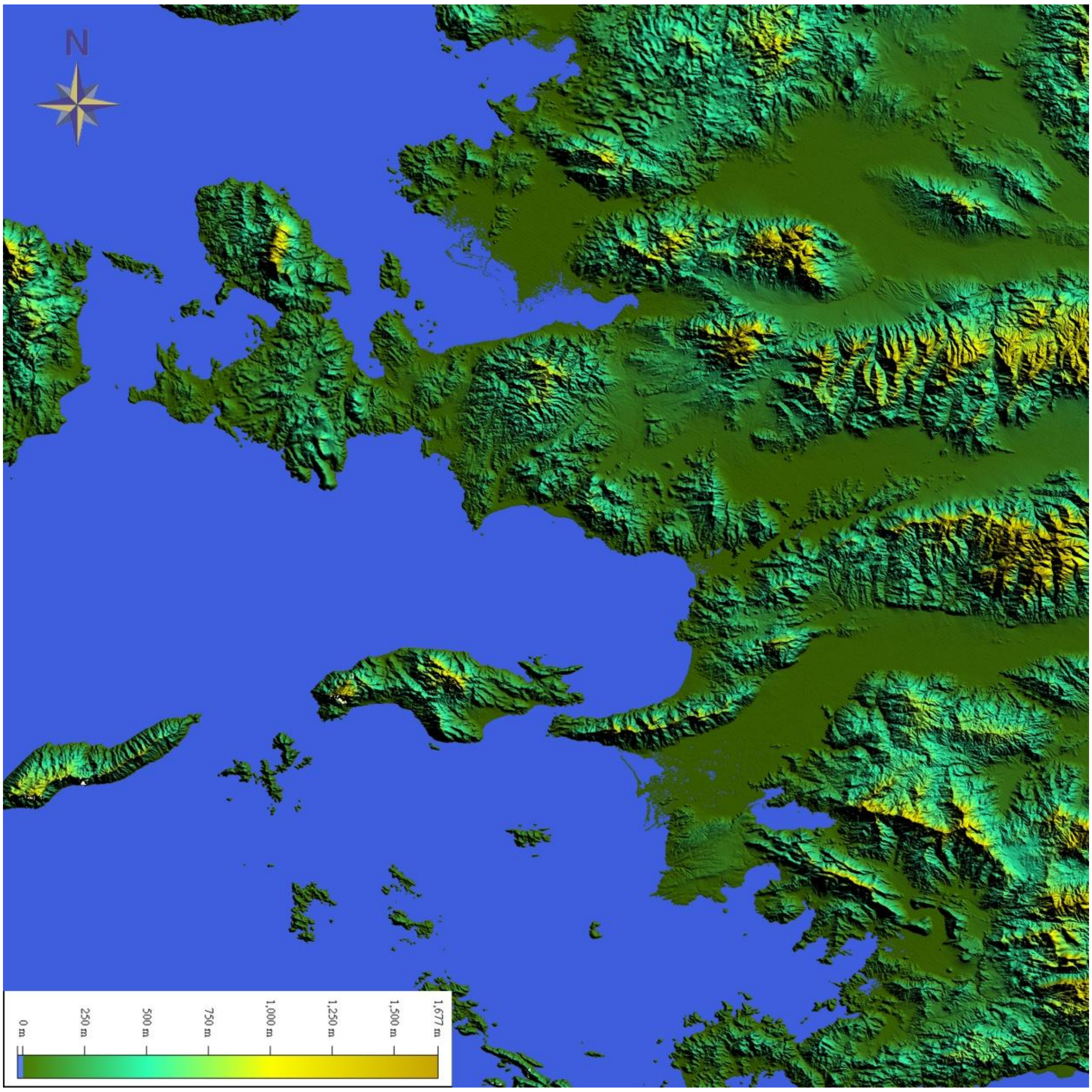


Figure 3.4 Topographic map of İzmir.

3.4.3 Meteorological Data

The meteorological conditions in İzmir and its surroundings were summarized from hourly observations in 4 different meteorological stations from 2008 to 2009. Table 3.4 shows the list of meteorological stations positioned in İzmir and its surroundings.

Surface data which were obtained from İzmir, Seferihisar, Aliağa and Manisa meteorological stations, contained hourly surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure and relative humidity. Upper air data which was obtained from İzmir meteorological station included upper air meteorological observations as twice daily sounding data (at the universial sounding times of 00 and 12 GMT).

Table 3.4 Meteorological stations these are used for CALMET and their locations.

NO	STATION CODE	STATION NAME	X COORDINATE	Y COORDINATE
1	17220	İZMİR	514837	4253539
2	17820	SEFERİHİSAR	485115	4228019
3	17787	ALİAĞA	497394	4294583
4	17186	MANİSA	537432	4274696

Missing values of temperature, cloud cover, ceiling height, surface pressure, and relative humidity at surface stations are internally replaced by values at the closest station with non - missing data. If the sounding data form upper air stations is missing, CALMET will interpolate to replace the missing data. The interpolation of wind data is performed with the u and v components, so both the wind speed and direction have to be present for either to be used. Because the model can not extrapolate upper air data, the top valid level must be at or above the model domain and the lowest (surface) level of the sounding must be valid (İm, 2000).

Temperature values in the atmosphere were recorded as hourly data in the meteorological stations of Turkish State Meteorological Service (DMİ) for the years 2008-2009. In winter the daily mean temperatures were observed in the range of 1.2–24.8 ^{o}C in İzmir. For daily maximum temperatures Aliağa stations had minimum value (-1.4) and the highest value (27.3) was observed in Manisa station. The avarage daily temperature was observed in Güzelyalı station as 12.03 in winter of 2008-09.

Generally humidity values in winter season are higher than summer values. Manisa station had the avearage maximum values (79%) during the winter. The average minimum humidity value (69%) was recorded in İzmir station for almost all months of winter.

Cloudiness values are expressed with the numbers between 0–10 in meteorological measurements of DMI stations. “0” means that there is no cloud in the sky and “10” means the sky is completely overcast. Cloudy sky decreases the incoming solar radiation and affects the vertical temperature profile of the atmosphere. Thus cloudiness is a very important meteorological parameter for air pollution (Elbir et. al., 2009). The maximum monthly mean cloudiness value was 9 in Manisa station.

Wind is one of the most important meteorological parameters affecting the air quality. Wind speed affects the dilution level while wind direction determines the areas that the pollutants will be transported. Winter season wind roses were plotted for four stations in İzmir and its surroundings using hourly wind speed and direction data from November 2008 to March 2009. By the help of these wind roses, the dominant wind directions in each station were determined. These wind roses are given in Figure 3.5, Figure 3.6, Figure 3.7 and Figure 3.8.

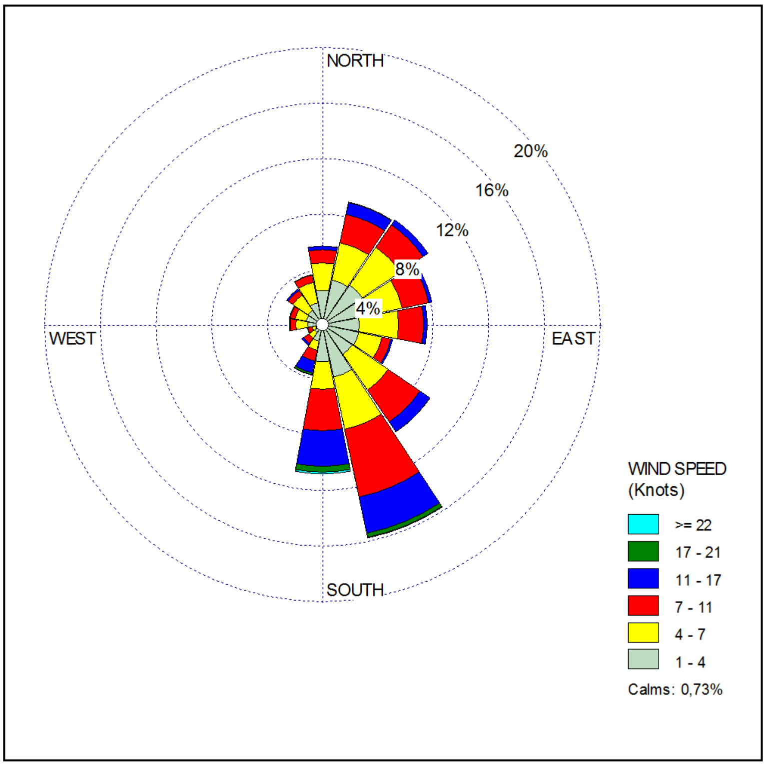


Figure 3.5 The wind rose in İzmir in 2008-09 winter season.

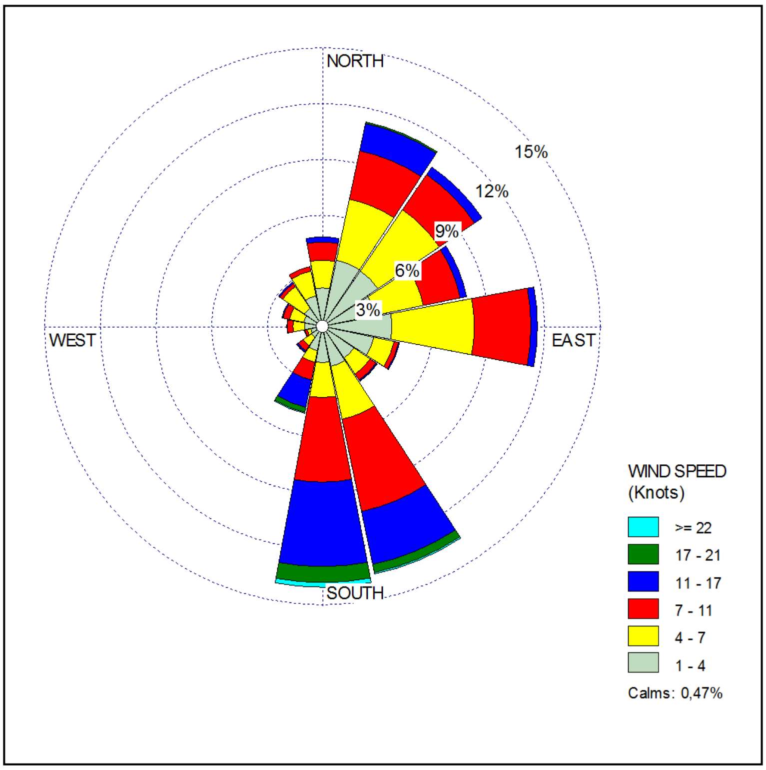


Figure 3.6 The wind rose in Aliağa in 2008-09 winter season.

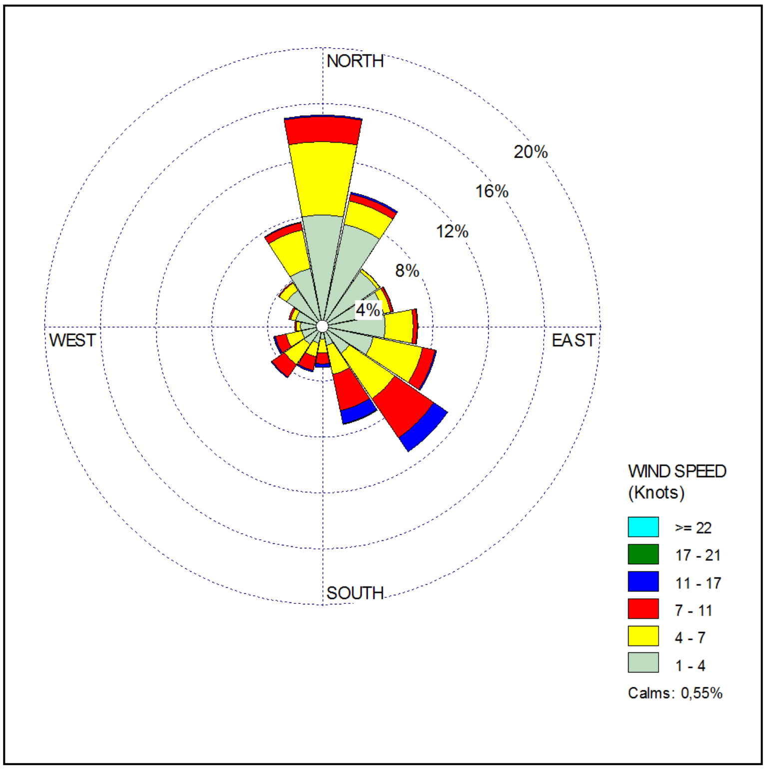


Figure 3.7 The wind rose in Seferihisar in 2008-09 winter season.

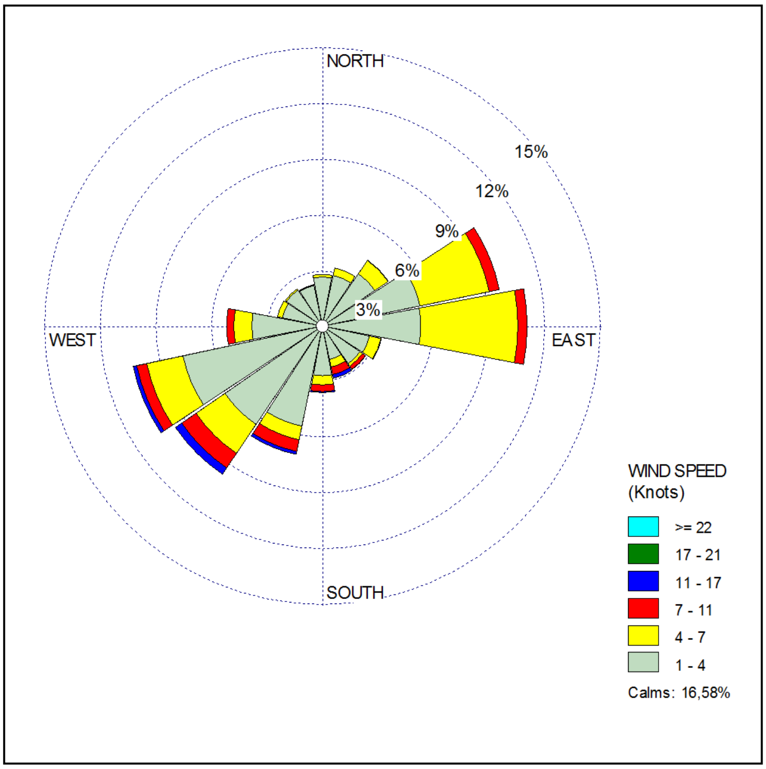


Figure 3.8 The wind rose in Manisa in 2008-09 winter season.

3.4.4 Source Characteristics

Emissions from residential sources, too small and difficult to be measured, were considered in a group as area sources. Consequently, domestic sources comprise area sources. Number of inhabitants, number of residences, types of fuels used, fuel consumption statistics and combustion characteristics are necassary for calculating the residential heating emissions. Population data was gained from the statistics of the last population census held by Turkish Statistical Institute in 2009.

For the modeling air pollutant emission from domestic heating in the city center of İzmir with CALPUFF dispersion model, the residential areas were represented as polygons. 657 polygons for the residential areas in the study area were drawn. Figure 3.9 demonstrated these 657 polygons. Effective heights of these area sources for modeling were supplied from İzmir 3D City Guide with using building heights.

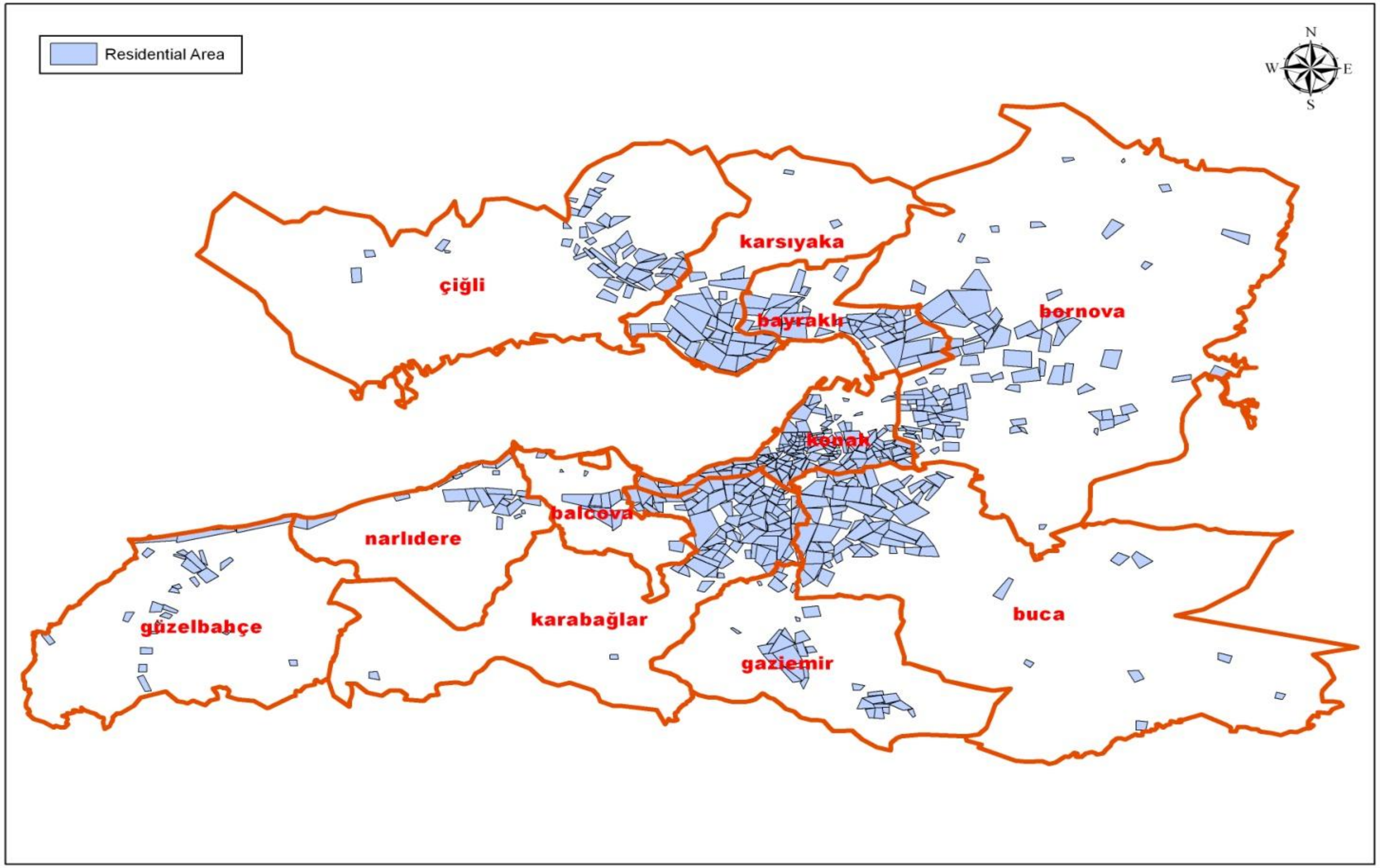


Figure 3.9 657 Residential areas in the city center of İzmir.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 The Total Emissions in the City Center of İzmir

Domestic heating is the one of the major air pollution sources in the city center of İzmir. Like other cities, the pollutant with the most potential for air quality problems from domestic heating in İzmir is particulate. During the winter approximately 4365 tons PM_{10} were released to air from households in the city. The majority of the PM_{10} emissions from domestic heating were from the burning of coal on uncontrolled burners. The highest PM_{10} emissions were released from Karabağlar and Konak where a greater proportion of households use coal. The important contaminants likely to be of concern in İzmir were PM_{10} and potentially SO_2. The main source of SO_2 emissions were fuel oil and lignite due to sulphur content of the fuel (Ağaçayak, 2007). Nearly 9720 tons SO_2 was released to atmosphere from households in İzmir during the study period. In addition, the major source of VOC emissions for residential sources is the coal and wood combustion (Klimont, Cofalla & Amann, 2000). The total VOC emissions of İzmir in 2008-09 winter season was approximately 5200 tons (Table 4.1). According to emission inventory results, 1250 tons/year NO_2 and 49750 tons/year CO were released to atmosphere from domestic heating in 2008-09 winter season. CO emissions had a strong seasonal variation configured mostly by emissions from domestic heating (Poupkou et. al., 2008b).

Table 4.1 The total emissions of İzmir in 2008-09 winter season.

DISTRICTS	**SO_2(tons/year)**	**NO_2(tons/year)**	**PM_{10}(tons/year)**	**CO(tons/year)**	**VOC(tons/year)**
Bayraklı	1001.6	129.0	449.8	5125.2	539.9
Bornova	1425.3	183.4	640.1	7293.6	768.3
Buca	1393.1	176.8	625.6	7127.5	750.6
Çiğli	595.7	77.3	267.5	3048.7	321.2
Gaziemir	311.5	45.6	139.9	1596.7	168.7
Güzelbahçe	113.6	13.9	51.0	580.8	61.1
Karabağlar	1708.7	211.0	767.3	8739.4	919.8
Konak	1772.7	217.4	796.0	9066.0	954.0
Karşıyaka	1061.6	161.1	476.9	5444.5	575.7
Balçova	138.8	17.0	62.3	709.9	74.7
Narlıdere	197.7	24.1	88.8	1010.8	106.4
Total	**9720.3**	**1256.6**	**4365.2**	**49743.1**	**5240.3**

As a result of the emission inventory study; SO_2, NO_2, PM_{10}, CO and VOC emissions in a winter season were calculated in all districts and villages in the city center of İzmir. The study area within the remaining districts, quarters and villages boundaries had been drawn with using 3-dimensional urban map of İzmir was prepared by İzmir Metropolitan Municipality. These drawn polygons was matched with the calculated loads of pollution by using geographical information system technology and prepared pollution maps in İzmir. These maps are given Figure 4.1-Figure 4.5. Due to their dense population, Karabağlar, Konak, Karşıyaka, Buca and Bornova regions in the city center of İzmir had high air pollutants emissions.

Perhaps a better indicator of the potential for ambient air quality issues is the representation of emissions in ton per km^2. Konak is the central district of İzmir had the highest area adjusted emission rates for SO_2 with 74.4 tons/km^2, for NO_2 with 9.1 tons/km^2, for PM_{10} with 33.4 tons/km^2, for CO with 380.3 tons/km^2 and for VOC with 40 tons/km^2. But Güzelbahçe which is located in south-eastern of the city, had the least area adjusted emission rates for SO_2 with 1.8 tons/km^2, for NO_2 with 0.2 tons/km^2, for PM_{10} with 0.8 tons/km^2, for CO with 9.1 tons/km^2 and for VOC with 0.9 tons/km^2. While this provides an indicator of the emission density, it is also not an ideal expression, as the housing density within the study areas will vary. Because, not residential areas which include quantities of rural land can be reduce the overall ton per km^2 emission rate.

In the south part of the city (Balçova and Narlıdere) a house's stack released nearly 0.005 tons/year SO_2, 0.001 tons/year NO_2, 0.002 tons/year PM_{10}, 0.023 tons/year CO, 0.002 tons/year VOC. But in the north part of the city (Bayraklı, Bornova and Karşıyaka) closely 0.01 tons/year SO_2, 0.001 tons/year NO_2, 0.005 tons/year PM_{10}, 0.052 tons/year CO, 0.005 tons/year VOC were released to atmosphere from a house's stack. The highest emissions were 0.011 tons/year SO_2, 0.001 tons/year NO_2, 0.005 tons/year PM_{10}, 0.056 tons/year CO, 0.006 tons/year VOC per a house's stack in the center districts (Konak, Karabağlar and Buca) of the city owing to dense population in 2008-09 winter season.

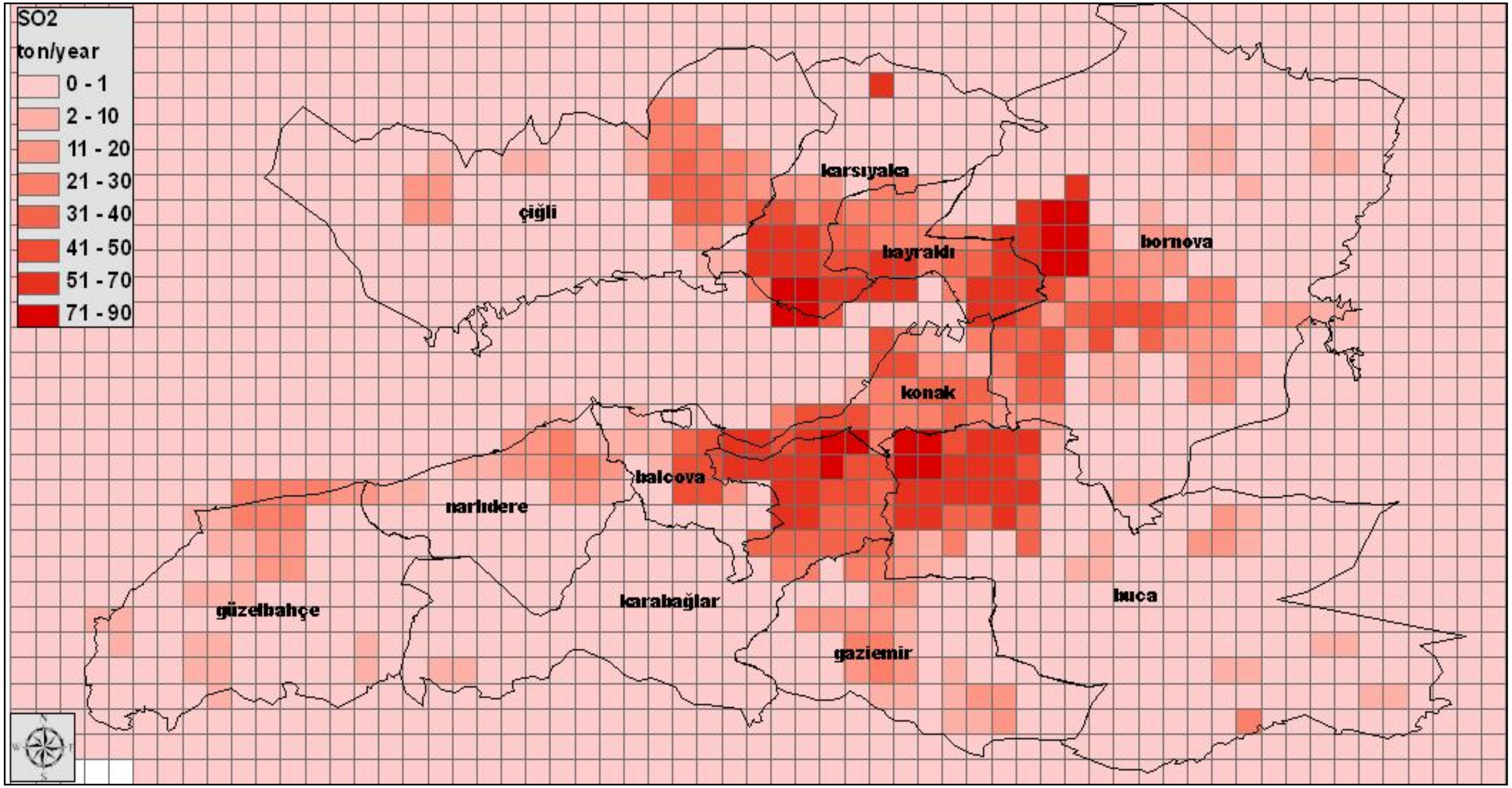


Figure 4.1 SO_2 emissions from domestic heating of residential areas in İzmir city center in 2008-09 winter season.

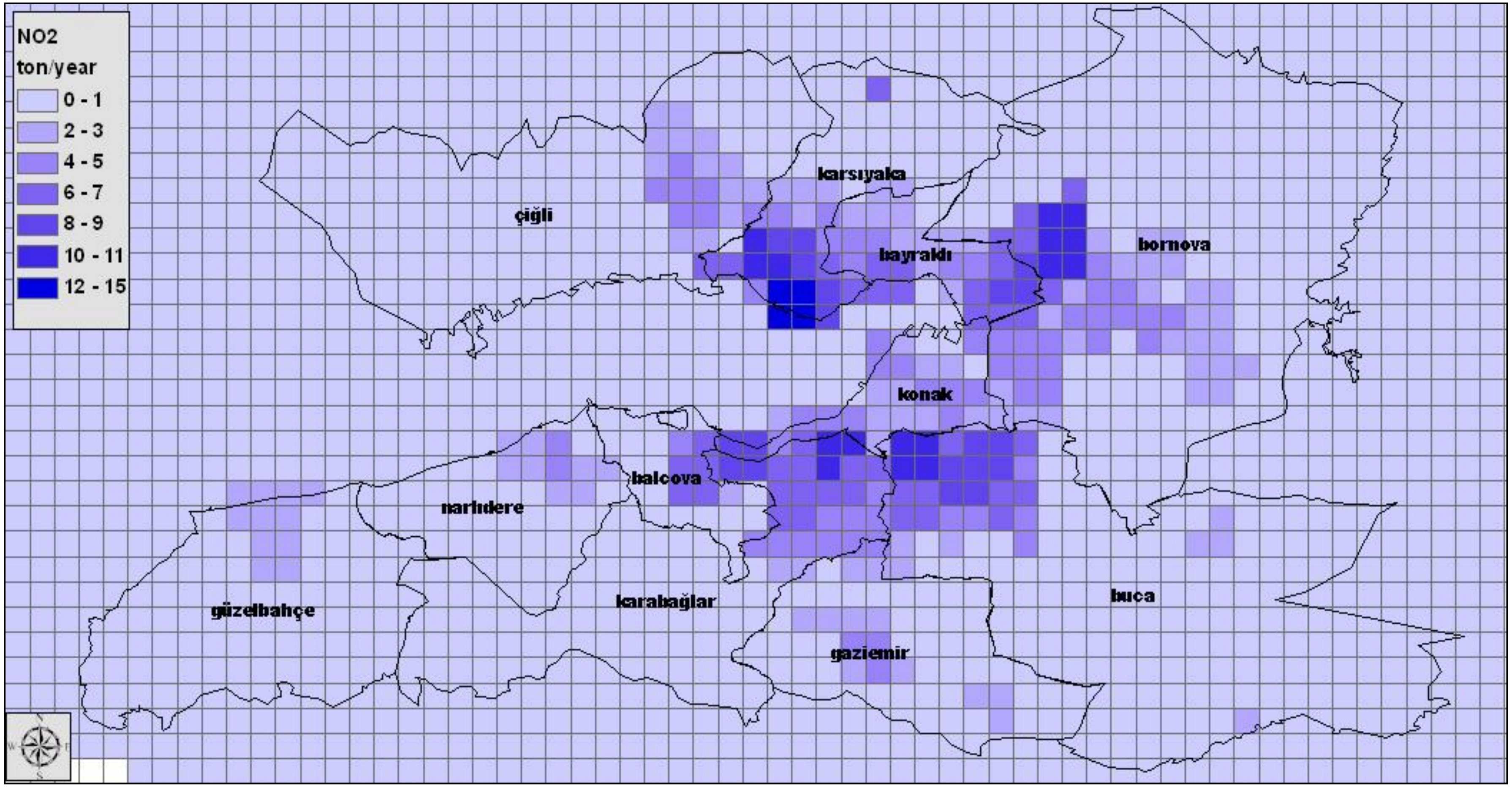


Figure 4.2 NO_2 emissions from domestic heating of residential areas in İzmir city center in 2008-09 winter season.

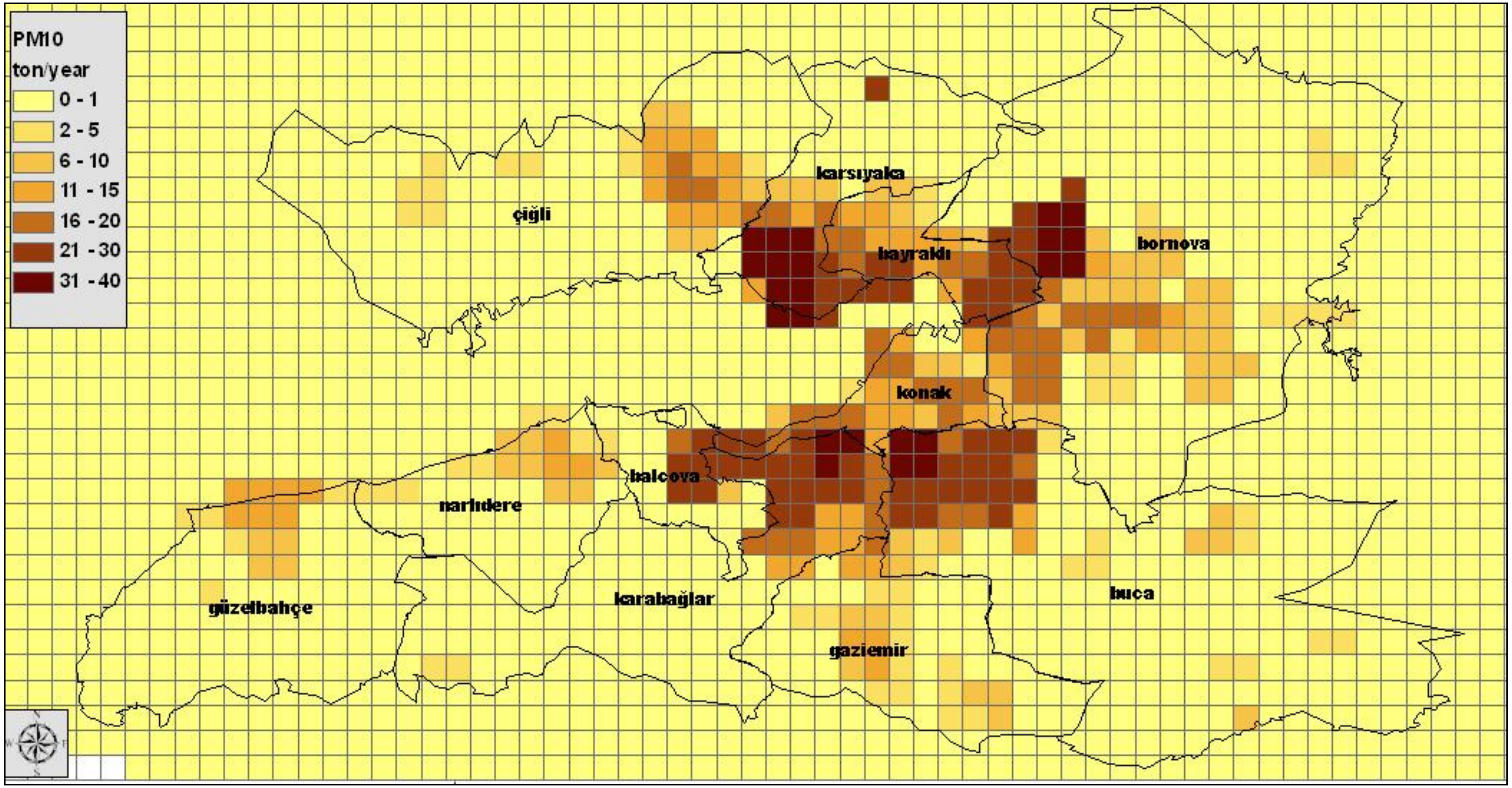


Figure 4.3 PM_{10} emissions from domestic heating of residential areas in İzmir city center in 2008-09 winter season.

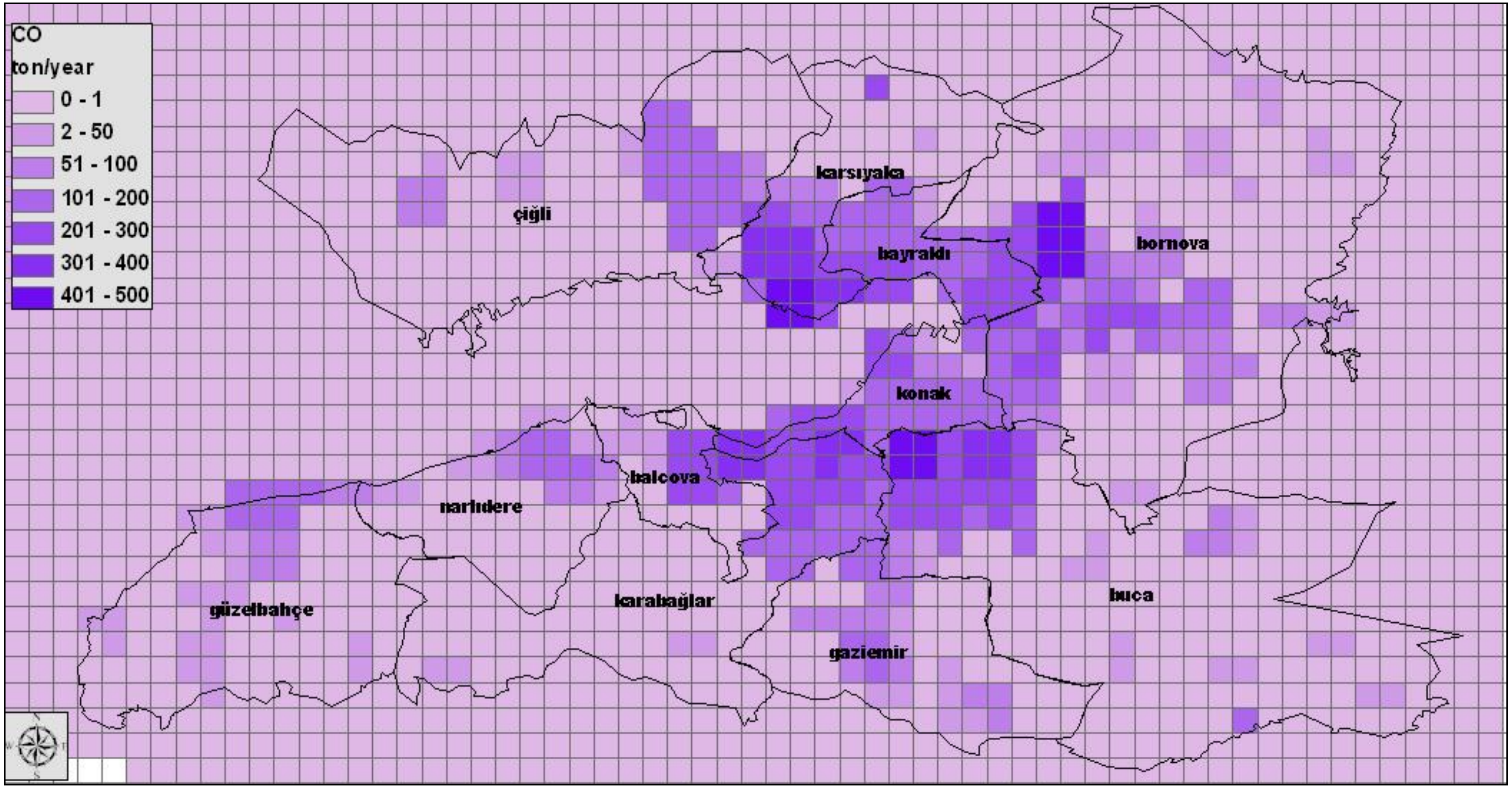


Figure 4.4 CO emissions from domestic heating of residential areas in İzmir city center in 2008-09 winter season.

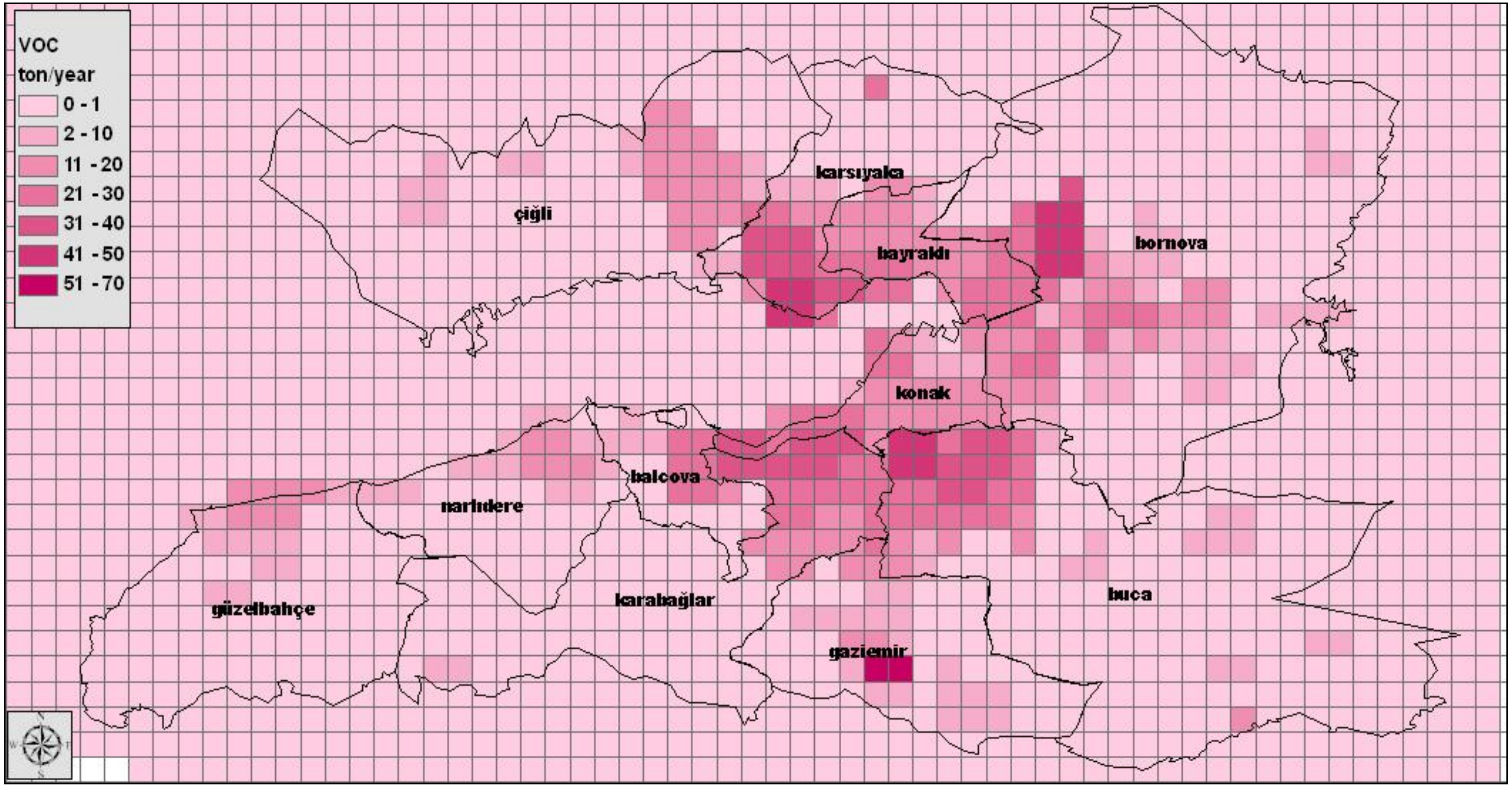


Figure 4.5 VOC emissions from domestic heating of residential areas in İzmir city center in 2008-09 winter season.

By the study, acquired results were compared to the others which were collected in the emission inventory in Clean Air Plan of 2000. In conclusion of this comparison, it is observed that especially SO_2 and PM_{10} values were decreased almost 80%. The most important fact is that coal consumption was also decreased and quality of the consumed coal was also increased at the same time. It is calculated in Clean Air Plan that SO_2 emission related to the domestic heating sources for winter months is 45419 tons/year while this study estimates 9677 tons/year for the 2008 – 2009 winter period. When PM_{10} values reviewed, calculations show 26213 tons/year for 2000 and 4346 tons /year for 2008-09 winter season (Müezzinoğlu et. al., 2001).

In a research project which was concluded in 2008 by DEU and with the support of TÜBİTAK and İzmir Metropolitan Municipality, air pollutants originated from urban traffic in İzmir Centrum have been determined. When winter emissions originated from traffic and domestic heating sources are compared, it is seen that domestic heating sources were higher. In winter months, total traffic emissions were 126 tons/year for SO_2; 966 tons/year for NO_2; 37 tons/year for PM_{10}, and 2160 tons/year for CO. Only NOx emissions were at the same order with residential emissions (Elbir et. al., 2010).

Elbir and colleagues prepared emission inventory of İstanbul, Turkey and calculated 10893 tons/year SO_2, 13631 tons/year PM_{10}, 7014 tons/year NO_2, 123510 tons/year CO and 18351 tons/year VOC emissions from domestic heating for 2007 winter season (Elbir et. al., 2009). The city center of İzmir emissions were lower than İstanbul's. Especially NOx emissions were seven times higher than domestic heating emissions in İzmir due to much more the usage of natural gas in İstanbul. The total air pollutant emissions from domestic heating in residential areas of the city center of Yalova (Irmak, 2005), Sakarya (Odabaş, 2009) and Zonguldak (Zeydan, 2008) were released to atmosphere less than the city center of İzmir. The results of the study were compared with the outputs of similar project in Table 4.2.

Table 4.2 Comparison of the city center of İzmir emissions in 2008-09 winter season to other cities emissions.

LOCATION	YEAR	SOURCE	SO_2	PM_{10}	NO_2	CO	VOC	Reference
İzmir	2008-09	DH	9677	4346	1251	49521	5217	
İzmir	2000	DH	45419	26213	20536	48320	10268	*Müezzinoğlu et.al. , 2000*
İzmir	2008	T	126	966.4	37.2	2160		*Elbir et. al. 2010*
Zonguldak	2008	DH	1703	426	625	18885	687	*Zeydan, 2008*
Sakarya	2007	DH	3428	857	265	9451		*Odabaş, 2009*
İzmir	2001	DH	8200	38433	887	1517	1216	*Elbir et. al., 2001*
İstanbul	2007	D H	10983	13631	7014	123510	18351	*Elbir et. al., 2009*
Yalova	2003-04	D H	1050	1448	192	3203		*Irmak, 2005*

DH: Domestic heating, T: Traffic

According to results of the study, a person in İzmir caused 3 kg SO_2, 1.3 kg PM_{10}, 0.4 kg NO_2, 15.1 kg CO and 1.6 kg VOC for domestic heating in 2008-09 winter season. Kecebaş calculated a release of 39.6 kg PM and 8.33 kg SO_2 per a person in Afyon (Kecebaş, Gedik & Kayfeci, 2010). In 1995 Atımtay determined 2.4 kg SO_x and 2 kg PM emissions per a person for domestic heating in Ankara (Atımtay, Güllü & Yetiş, 1995). Turalıoğlu achieved a similar study for Erzurum in 2005. It is estimated that a person who lives in Erzurum, released 21.2 kg SO_2 and 27.9 kg PM to atmosphere (Turalıoğlu, 2005).

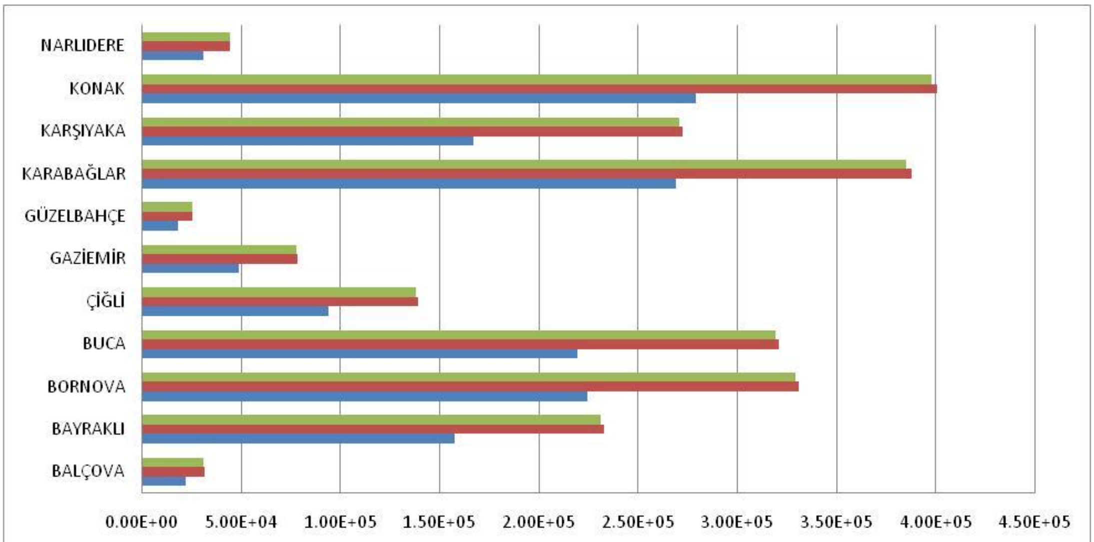
Domestic heating of residential areas in the city which has a large and intensified population with the growing influx of migrants, becomes a meaningful contributor of GHG (Kumar, Tandon & Madan, 2009). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) are the six main GHGs, covered under the Kyoto Protocol (Anderson, 2008). But for greenhouse gases emissions inventory of İzmir; CO_2, CH_4 and N_2O are chosen due to IPCC have emission factors of only these compounds.

GHGs emissions of study area for domestic heating were 2250018 tons/year CO_2, 33 tons/year N_2O and 10427 tons/year CH_4 according to the calculations made by using CORINAIR's emission factors in 2008-09 winter season. Although, 1603465 tons/year CO_2, 17 tons/year N_2O and 2027 tons/year CH_4 were calculated with using USEPA's emission factors, 2264046 tons/year CO_2, 35 tons/year N_2O and 6956 tons/year CH_4 were calculated with using IPCC's emission factors in the study area. The three methods were compared for estimating greenhouse gases and the results calculated with IPCC's emission factors turn out to be higher than those calculated with USEPA and CORINAIR. Greenhouse gases emissions of İzmir's city center region for domestic heating is given in Table 4.3.

Table 4.3 Greenhouse gases emissions of study area for domestic heating in 2008-09 winter season.

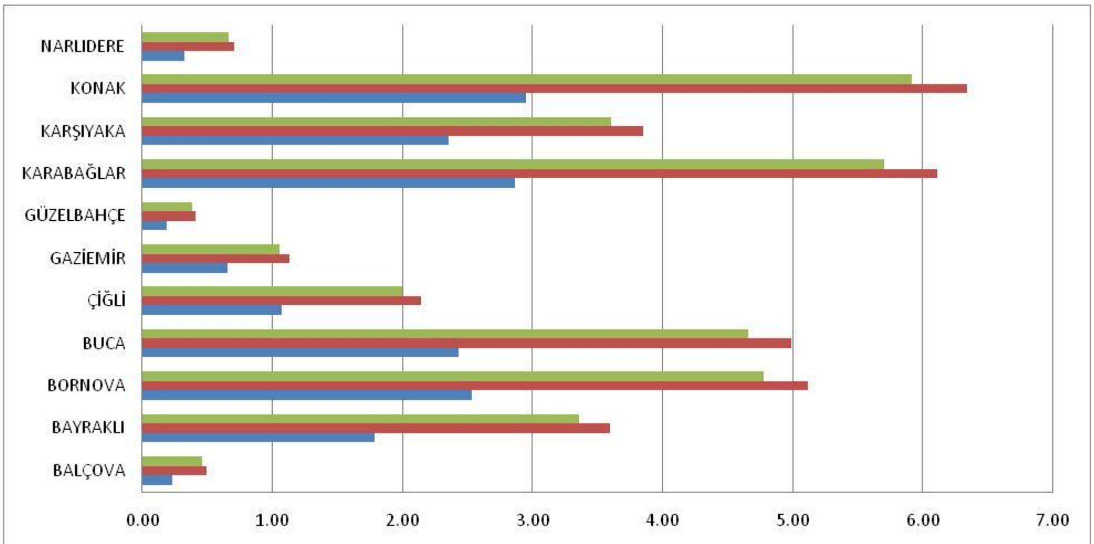
	CO_2(tons/year)	**N_2O(tons/year)**	**CH_4(tons/year)**
USEPA	1603465.5	17.4	2027.4
CORINAIR	2250018.3	32.6	10427.1
IPCC(2006)	2264046.4	34.9	6955.7

Figure 4.6, Figure 4.7 and Figure 4.8 show the GHGs emissions of İzmir's districts. Konak and Karabağlar have the biggest shares in domestic-based GHGs.



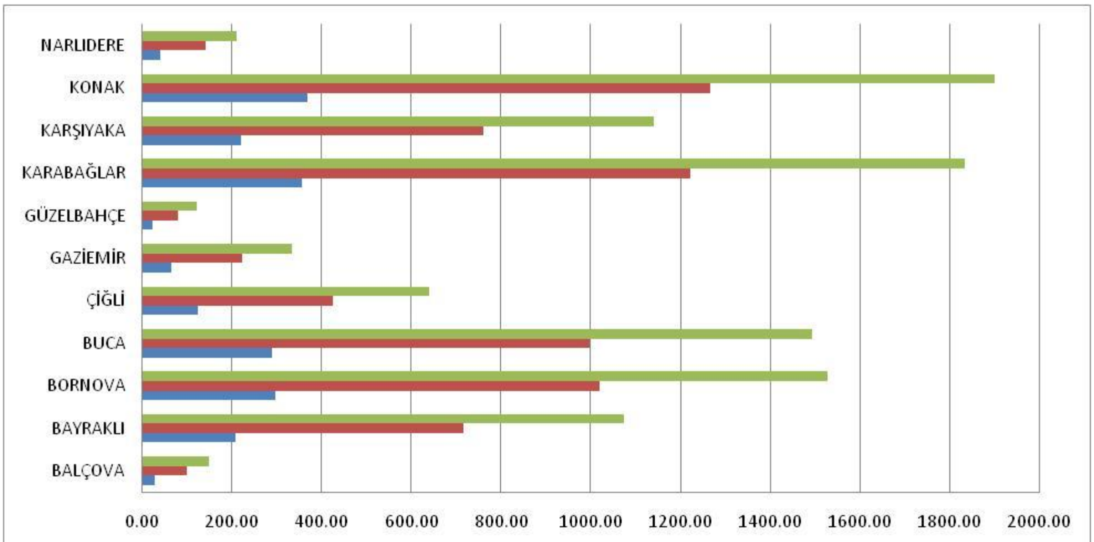
	BALÇOVA	BAYRAKLI	BORNOVA	BUCA	ÇİĞLİ	GAZİEMİR	GÜZELBAHÇE	KARABAĞLAR	KARŞIYAKA	KONAK	NARLIDERE
CORINAIR	3.11E+04	2.31E+05	3.29E+05	3.19E+05	1.38E+05	7.76E+04	2.54E+04	3.85E+05	2.71E+05	3.98E+05	4.43E+04
IPCC	3.13E+04	2.33E+05	3.31E+05	3.21E+05	1.39E+05	7.81E+04	2.56E+04	3.88E+05	2.72E+05	4.01E+05	4.46E+04
USEPA	2.19E+04	1.58E+05	2.25E+05	2.19E+05	9.39E+04	4.91E+04	1.79E+04	2.69E+05	1.67E+05	2.79E+05	3.11E+04

Figure 4.6 CO_2 emission of İzmir districts in 2008-09 winter season.



	BALÇOVA	BAYRAKLI	BORNOVA	BUCA	ÇİĞLİ	GAZİEMİR	GÜZELBAHÇE	KARABAĞLAR	KARŞIYAKA	KONAK	NARLIDERE
CORINAIR	0.46	3.35	4.77	4.66	2.00	1.05	0.38	5.71	3.60	5.92	0.66
IPCC	0.50	3.59	5.11	4.99	2.14	1.13	0.41	6.11	3.85	6.34	0.71
USEPA	0.23	1.78	2.53	2.43	1.07	0.66	0.19	2.87	2.35	2.95	0.33

Figure 4.7 N_2O emission of İzmir districts in 2008-09 winter season.



	BALÇOVA	BAYRAKLI	BORNOVA	BUCA	ÇİĞLİ	GAZİEMİR	GÜZELBAHÇE	KARABAĞLAR	KARŞIYAKA	KONAK	NARLIDERE
CORINAIR	148.87	1074.38	1528.93	1494.27	639.05	334.33	121.80	1832.62	1139.64	1901.19	211.98
IPCC	99.25	716.67	1019.87	996.60	426.31	223.36	81.20	1221.89	761.72	1267.52	141.32
USEPA	28.94	208.90	297.28	290.51	124.26	65.07	23.67	356.23	221.85	369.54	41.20

Figure 4.8 CH_4 emission of İzmir districts in 2008-09 winter season.

Turkey prepared its first National Inventory Report (NIR) and tables for the period 1990 – 2004 and presented to The United Nations Framework Convention on Climate Change (UNFCCC) 2006. Then, the Kyoto Protocol was confirmed by

Turkey in 2009. As an Annex I party to convention, Turkey is required to upgrade annual inventories on emissions and removals of GHGsnot controlled by the Montreal Protocol using the methodology approved by the UNFCCC. So Turkey has to prepare its national inventory report and tables every year. National inventory report and tables are prepared by TurkStat and presented to the UNFCCC Secretariat by TurkStat as the central point of Turkish National Emission Inventory. Recently Turkey has prepared its fifth NIR for the year 2008. This report presented the national inventory of greenhouse gas (GHG) emissions and removals from 1990 to 2008. The amount of greenhouse gases from residential of five country in 2008 are given in Table 4.4 is prepared with 2008 national inventory reports and tables of Turkey, Germany, Japan, Great Britian-Ireland and USA (2010 Annex I Party GHG Inventory Submissions, 2010). According to 2008 national inventory reports and tables USA had the highest greenhouse gases emissions from residential in the world.

Table 4.4 The amount of greenhouse gases from residential of five countries in 2008

	Emission (tons/year)	**Liquid Fuels**	**Solid Fuels**	**Gaseous Fuels**	**Biomass**	**Residential (Total)**
Germany	CO_2	49803481.0	4600117.0	50008000.0	21238464.0	104411598.0
	CH_4	181.2	4961.2	2075.1	20734.3	27951.7
	N_2O	369.2	398.0	224.5	319.4	1311.1
Japan	CO_2	38466991.4	NA	20556147.5	105768.6	59023138.8
	CH_4	4461.2	NA	1898.8	278.5	6638.5
	N_2O	228.6	NA	38.0	3.6	270.3
Great Britain & Ireland	CO_2	8921035.9	3224976.3	67260702.0	1532254.3	79406714.1
	CH_4	1250.0	11703.9	6563.3	4503.6	24020.8
	N_2O	84.5	141.9	131.3	60.0	417.7
USA	CO_2	77323999.4	706897.2	264687907.5	50527164.0	342718804.1
	CH_4	11234.2	2254.4	23709.8	139583.9	176782.3
	N_2O	674.0	11.3	474.2	1861.1	3020.6
Turkey	CO_2	4607958.9	26669979.0	16945978.6	NA	48223916.6
	CH_4	704.8	84341.4	1572.0	59732.1	146350.3
	N_2O	42.3	393.6	31.4	796.4	1263.7

* UNFCCC

According to 2008 national inventory reports and tables of Turkey, 48223916 tons CO_2, 1264 tons N_2O and 146350 tons CH_4 released to atmosphere from residential in 2008 (TÜİK, 2010). İzmir is contributing with about 5% of total greenhouse gases emissions like as total population of Turkey.

4.2 Modeling Results

The predicted average concentrations of 2008-09 winter season due to domestic heating emissions were individually plotted in the form of maps for five pollutants (PM_{10}, SO_2, NO_2, VOC and CO) by ArcMap 10. Seasonal variations on meteorology can affect the transportation of air pollutants. Specially, wind direction and wind speed can cause serious changes on the direction of plume. All these maps are demonstrated in the subsequent figures to show the changes of month by month. The maximum average concentrations during the winter of 2008-2009 were seen at Gulf of İzmir. The results showed that the most affected region was Balçova, Karabağlar, Konak and Karşıyaka which are central districts in the city from domestic heating emissions. According to the model results the eastern part of the city was the less polluted than other areas.

The maximum annual average concentration of SO_2 was approx. 87 $\mu g/m^3$ in winter. The maximum monthly SO_2 concentration in January was calculated as 159 $\mu g/m^3$. The maximum daily SO_2 concentration in 13 January 2009 was calculated as 1200 $\mu g/m^3$. The maximum daily SO_2 concentration for this sampling day was higher than the daily limit value (2009) of 370 $\mu g/m^3$ according to the Air Quality Assessment and Management Regulations. The maximum hourly SO_2 concentration in January and February was calculated as 3487 and 2000 $\mu g/m^3$. The maximum hourly SO_2 concentration for this sampling day was higher than the hourly limit value (2009) of 900 $\mu g/m^3$ according to the Air Quality Assessment and Management Regulations. The map of the winter month's average SO_2 concentrations calculated by CALPUFF model were given between Figure 4.9 - Figure 4.13. The highest daily concentrations and coordinates are given at Table 4.5.

Table 4.5 The highest daily SO_2 concentrations and coordinates at each month in 2008-09 winter season.

Month	**X(UTM)**	**Y(UTM)**	**SO_2 Con.**	**Year**	**Date**
November	500780	4249647	400	2008	27
December	492780	4247647	243	2008	6
January	506780	4243647	1200	2009	13
February	502780	4247647	563	2009	3
March	514780	4263647	348	2009	30

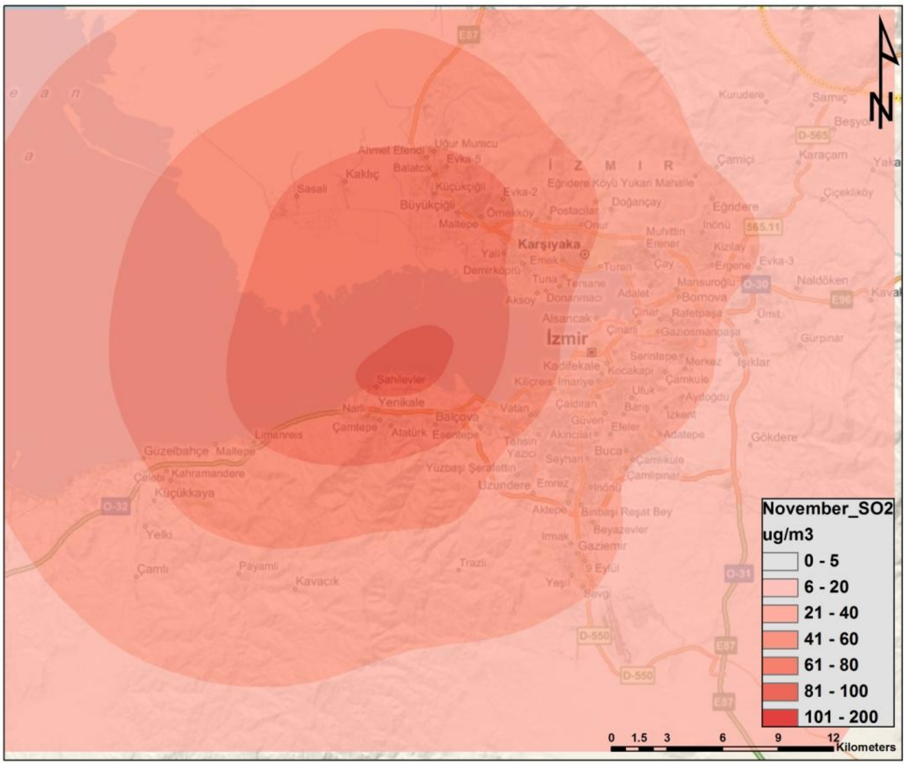


Figure 4.9 The monthly average SO_2 concentrations in November (2008).

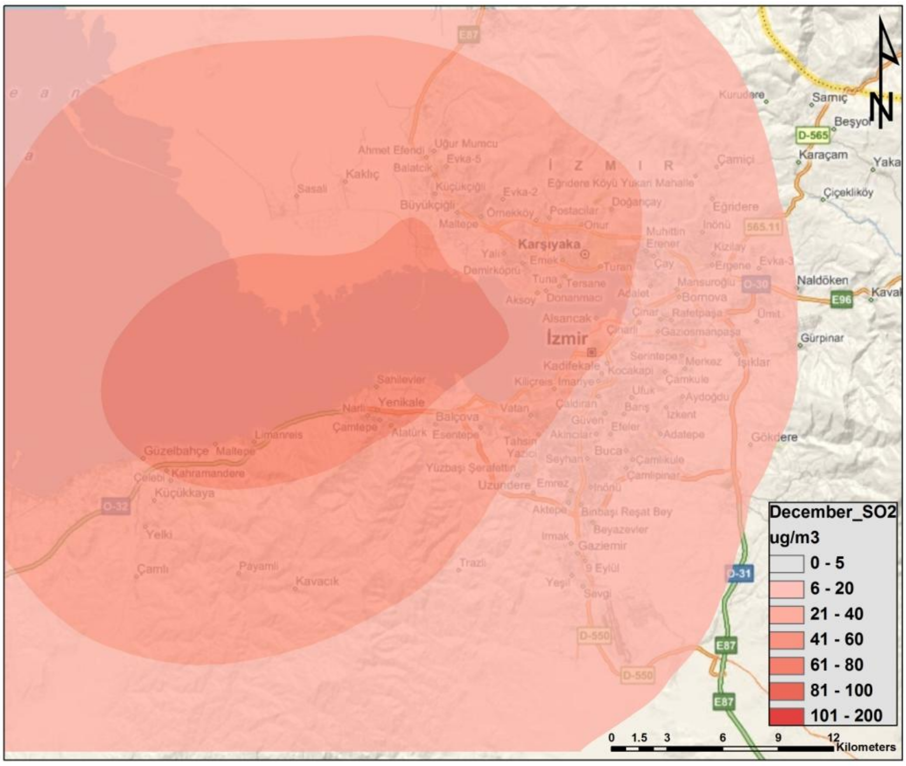


Figure 4.10 The monthly average SO_2 concentrations in December (2008).

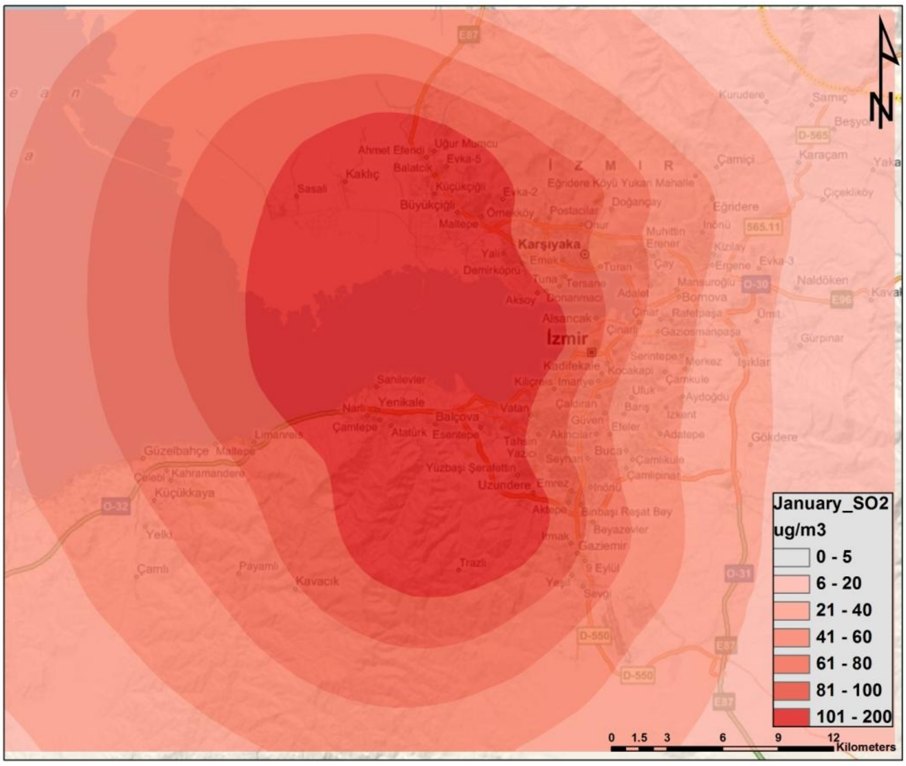


Figure 4.11 The monthly average SO_2 concentrations in January (2009).

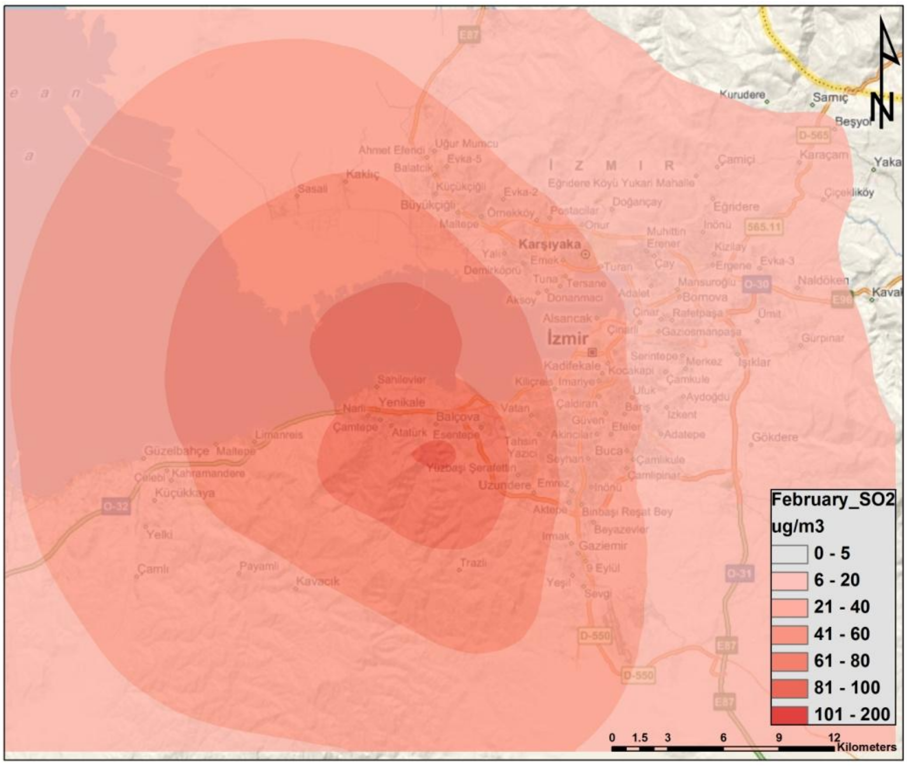


Figure 4.12 The monthly average SO_2 concentrations in February (2009).

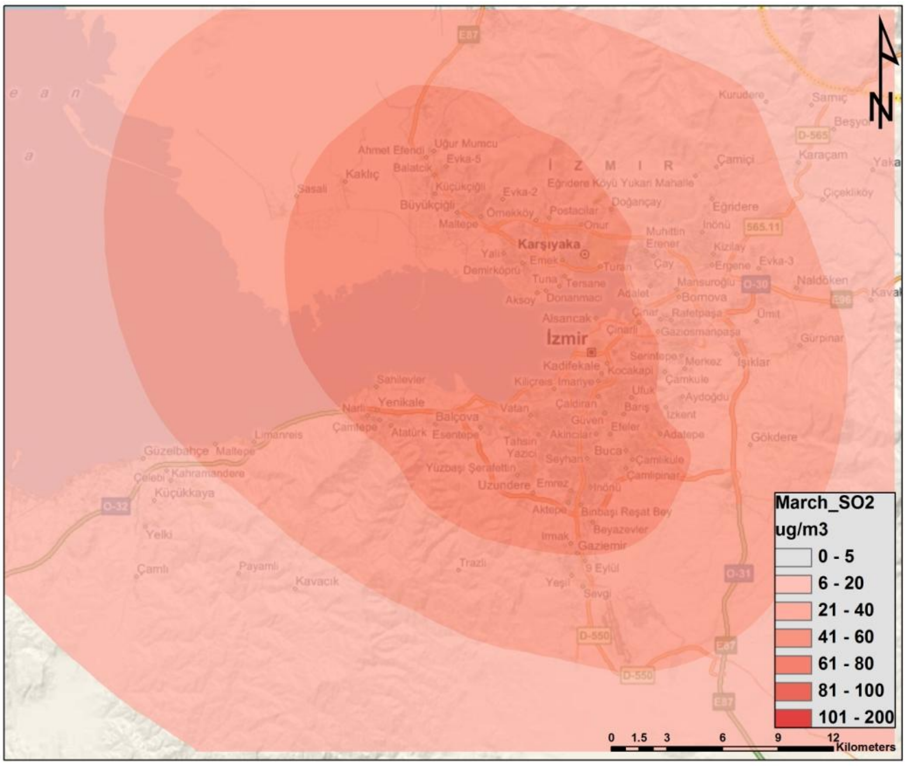


Figure 4.13 The monthly average SO_2 concentrations in March (2009).

The maximum annual average concentration of PM_{10} was approx. 39 µg/m^3 in winter. The maximum monthly PM_{10} concentration in January was calculated as 71 µg/m^3. The maximum daily PM_{10} concentration in 13 January 2009 was calculated as 539 µg/m^3. The maximum daily PM_{10} concentration for this sampling day was higher than the daily limit value (2009) of 260 µg/m^3 according to the Air Quality Assessment and Management Regulations. The maximum hourly PM_{10} concentration in November, January and February was calculated as 671, 1728 and 898 µg/m^3. The map of the winter month's average PM_{10} concentrations calculated by CALPUFF model is given in Figure 4.14-Figure 4.18. The highest daily concentrations and coordinates are given at Table 4.6.

Table 4.6 The highest daily PM_{10} concentrations and coordinates at each month in 2008-09 winter season.

Month	X(UTM)	Y(UTM)	PM_{10} Con.	Year	Date
November	500780	4249647	180	2008	26
December	492780	4247647	109	2008	6
January	506780	4243647	539	2009	13
February	502780	4247647	253	2009	3
March	504780	4263647	156	2009	30

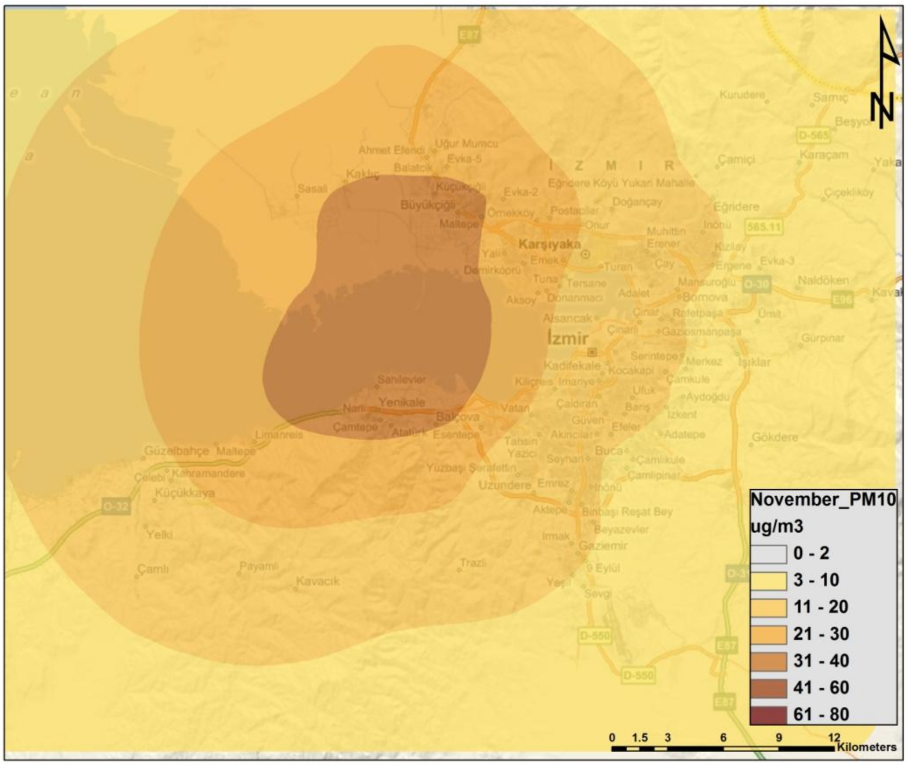


Figure 4.14 The monthly average PM_{10} concentrations in November (2008).

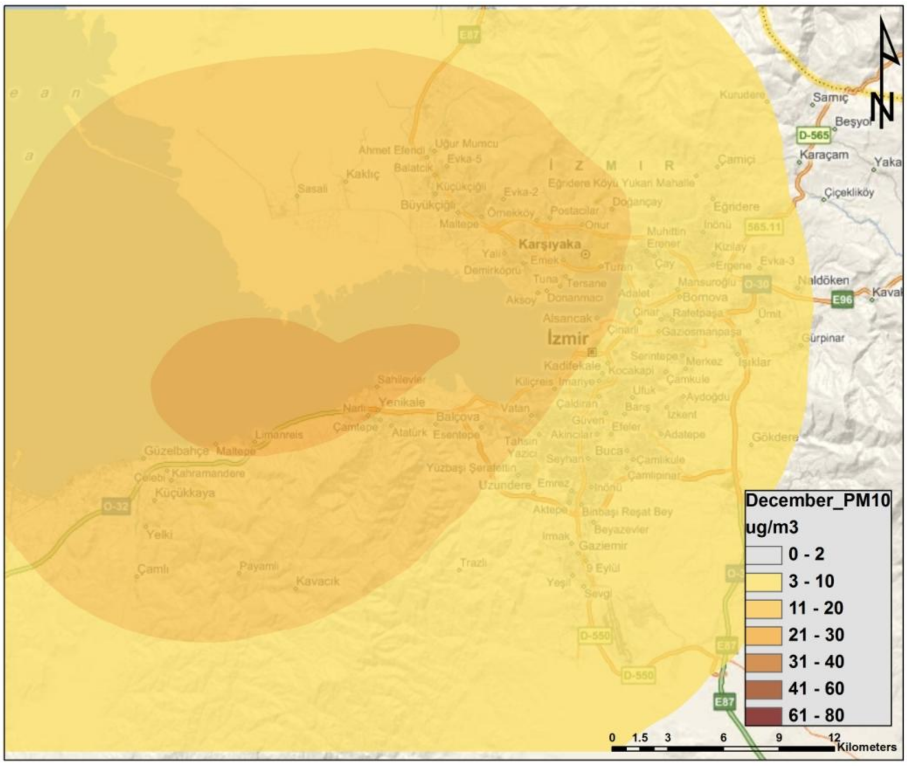


Figure 4.15 The monthly average PM_{10} concentrations in December (2008).

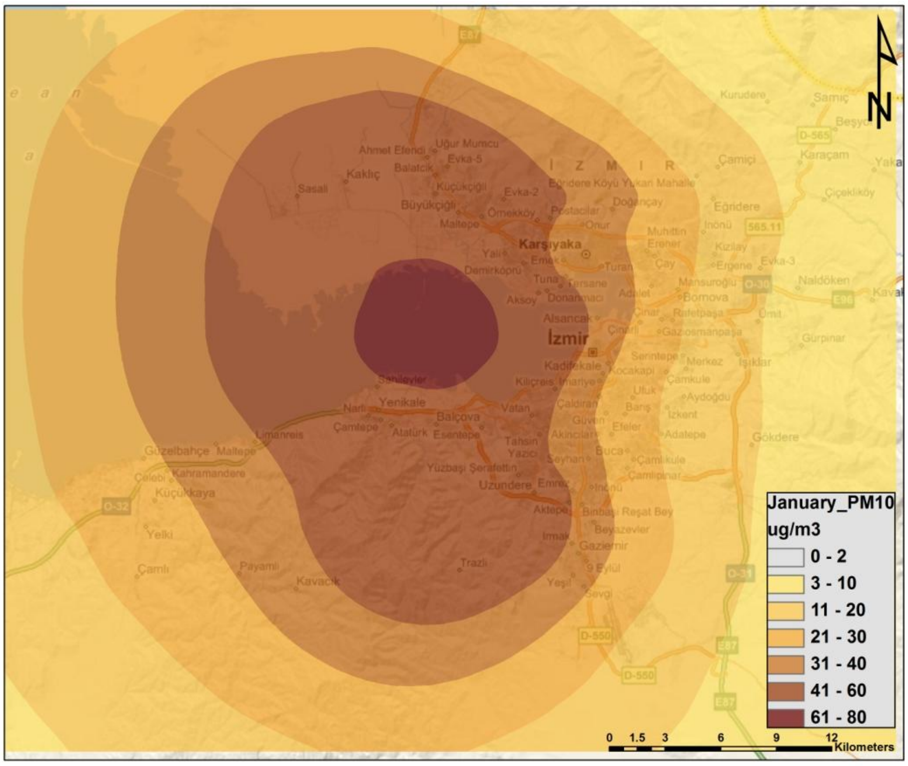


Figure 4.16 The monthly average PM_{10} concentrations in January (2009).

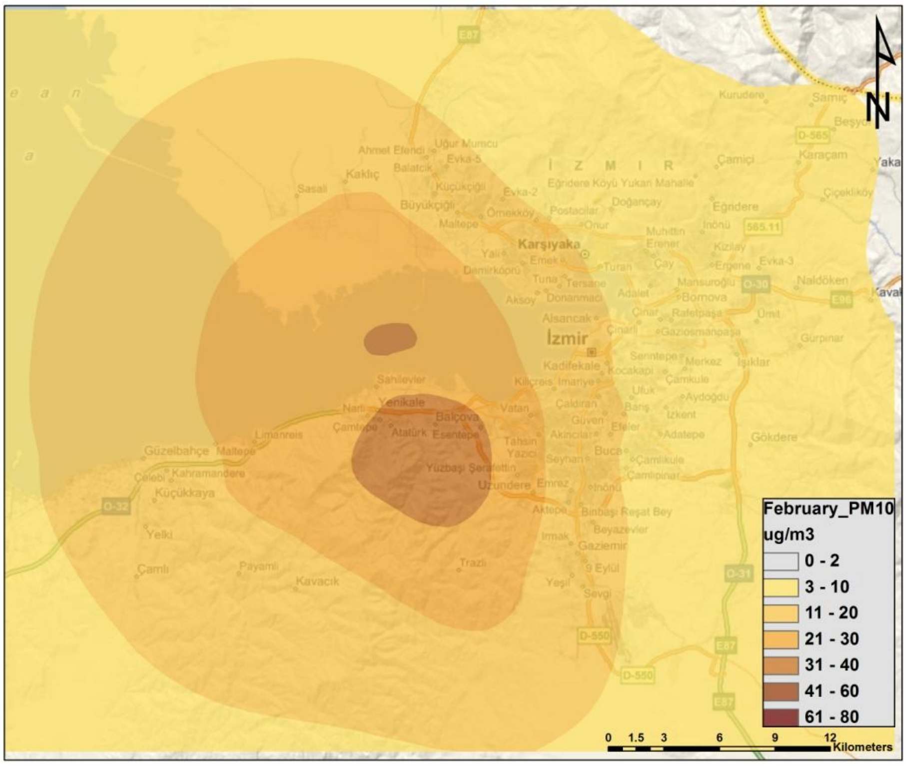


Figure 4.17 The monthly average PM_{10} concentrations in February (2009).

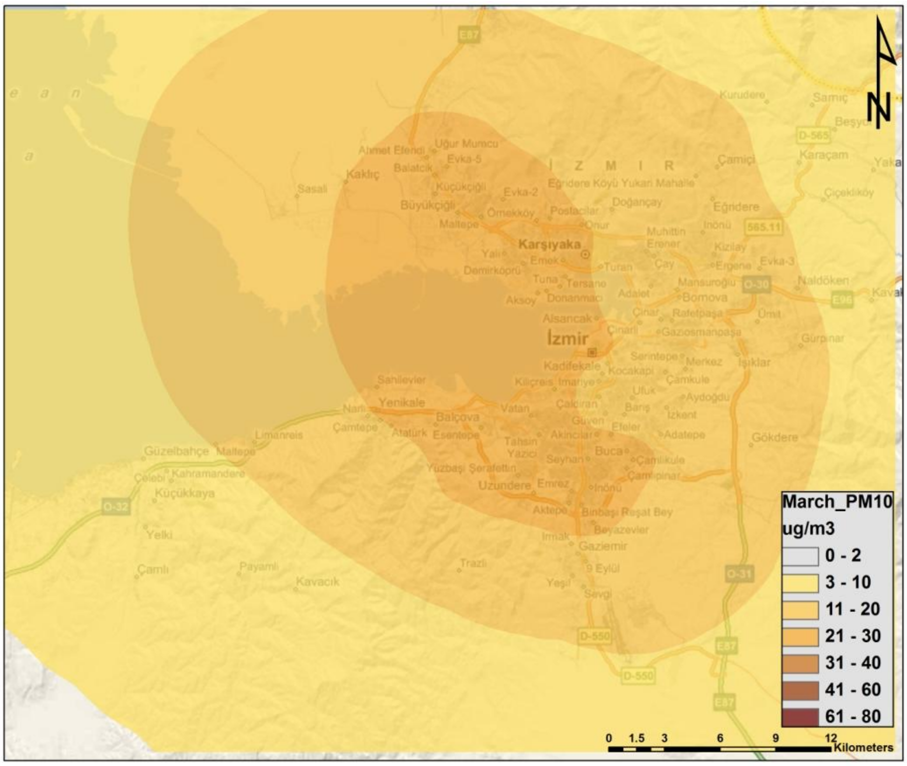


Figure 4.18 The monthly average PM_{10} concentrations in March (2009).

The maximum annual average concentration of NO_2 was approx. 11 μg/m^3 in winter. The maximum monthly NO_2 concentration in January was calculated as 21 μg/m^3. The maximum daily NO_2 concentration in 13 January 2009 was calculated as 153 μg/m^3. The maximum daily NO_2 concentration for this sampling day was lower than the daily limit value (2009) of 300 μg/m^3 according to the Air Quality Assessment and Management Regulations. The maximum hourly NO_2 concentration in November, January and February was calculated as 184, 485 and 251 μg/m^3. The map of the winter months average NO_2 concentrations calculated by CALPUFF model is given in Figure 4.19-Figure 4.23. The highest daily concentrations and coordinates are given at Table 4.7.

Table 4.7 The highest daily NO_2 concentrations and coordinates at each month in 2008-09 winter season.

Month	X(UTM)	Y(UTM)	NO_2 Con.	Year	Date
November	500780	4249647	49	2008	26
December	492780	4247647	30	2008	6
January	506780	4243647	153	2009	13
February	502780	4247647	70	2009	3
March	504780	4263647	48	2009	30

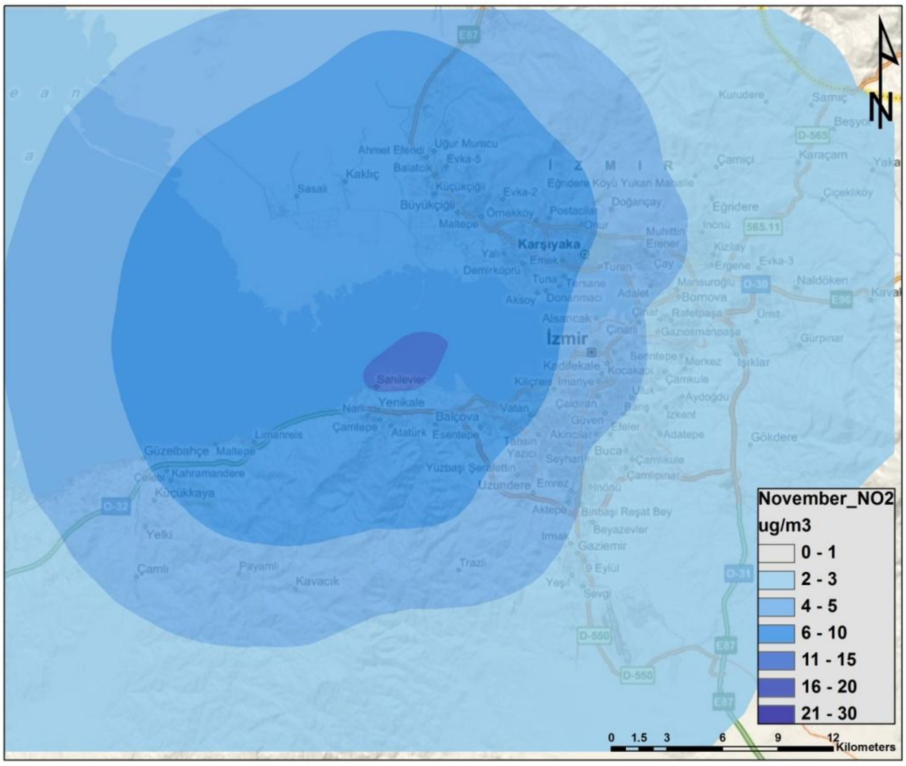


Figure 4.19 The monthly average NO_2 concentrations in November (2008).

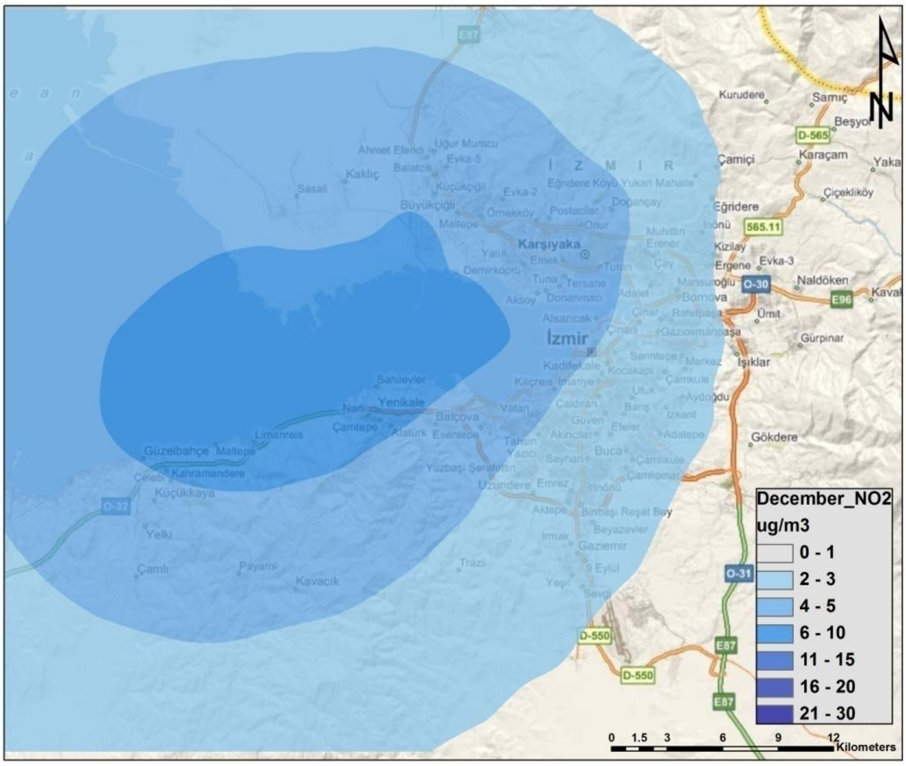


Figure 4.20 The monthly average NO_2 concentrations in December (2008).

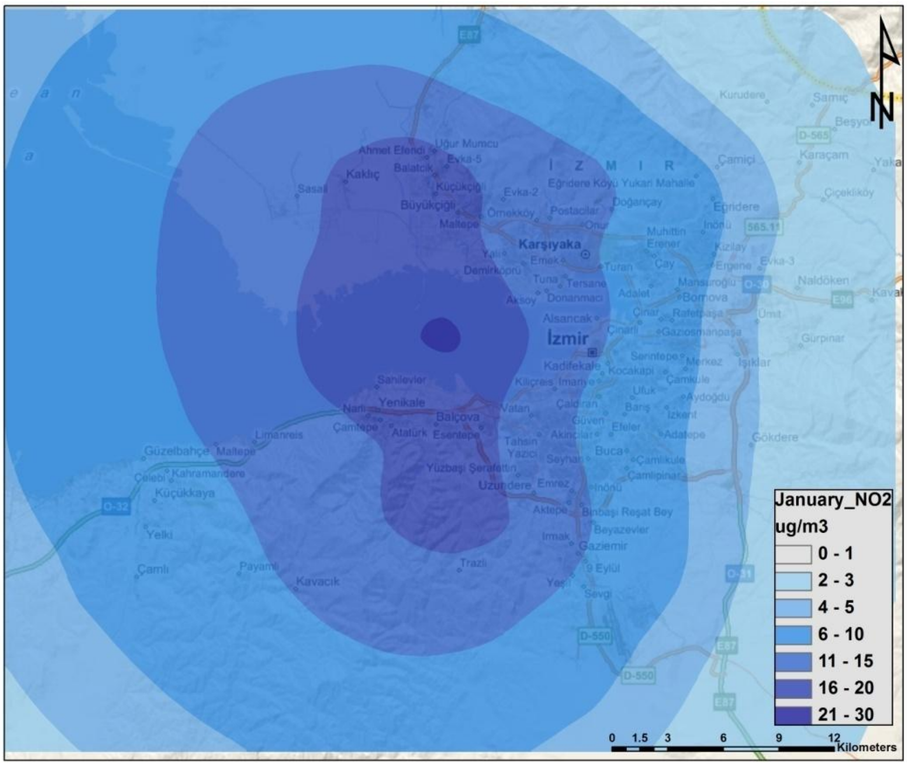


Figure 4.21 The monthly average NO_2 concentrations in January (2009).

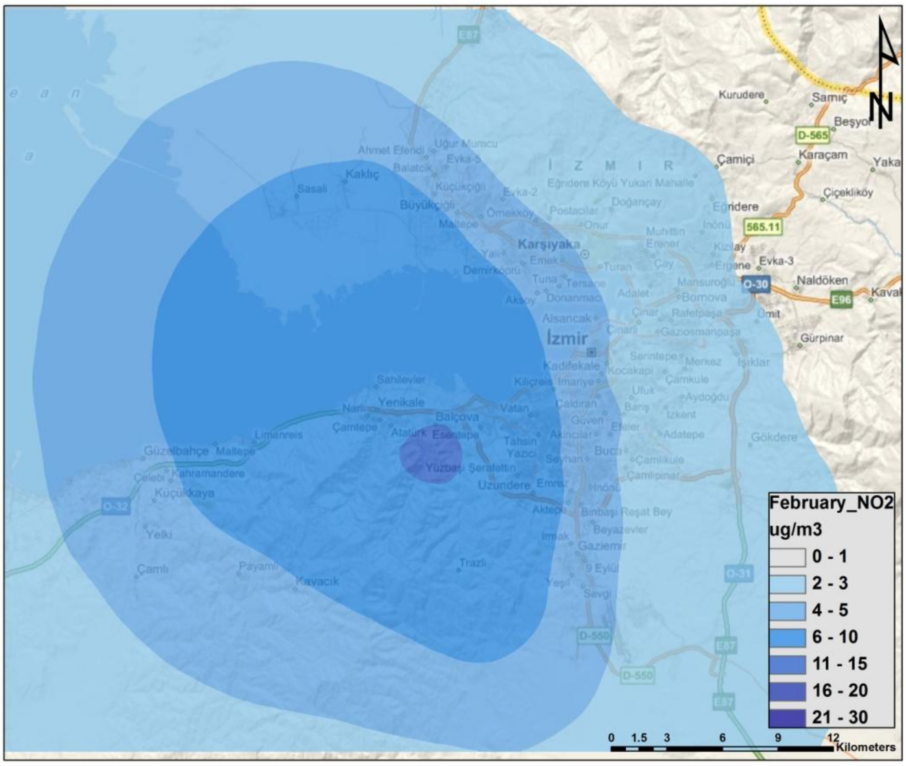


Figure 4.22 monthly average NO_2 concentrations in February (2009).

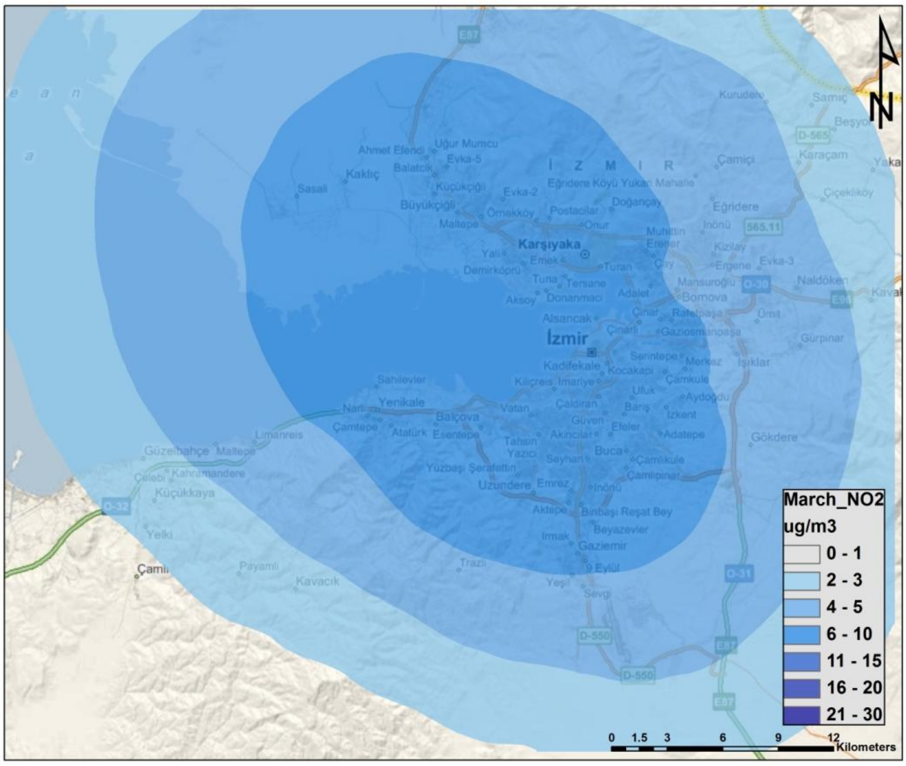


Figure 4.23 The monthly average NO_2 concentrations in March (2009).

The maximum annual average concentration of CO was approx. 443 μg/m^3 in winter. The maximum monthly CO concentration in January was calculated as 815 μg/m^3. The maximum daily CO concentration in 13 January 2009 was calculated as 6141 μg/m^3. The maximum daily CO concentration for this sampling day was lower than the daily limit value (2009) of 26 mg/m^3 according to the Air Quality Assessment and Management Regulations. The maximum hourly CO concentration in November, January and February was calculated as 7637, 19683 and 10232 μg/m^3. The map of the winter months average CO concentrations calculated by CALPUFF model is given in Figure 4.19-Figure 4.23. The highest daily concentrations and coordinates are given at Table 4.8.

Table 4.8 The highest daily CO concentrations and coordinates at each month in 2008-09 winter season..

Month	X(UTM)	Y(UTM)	CO con	Year	Date
November	500780	4249647	2048	2008	26
December	492780	4247647	1242	2008	6
January	506780	4243647	6141	2009	13
February	502780	4247647	2876	2009	3
March	504780	4263647	1781	2009	30

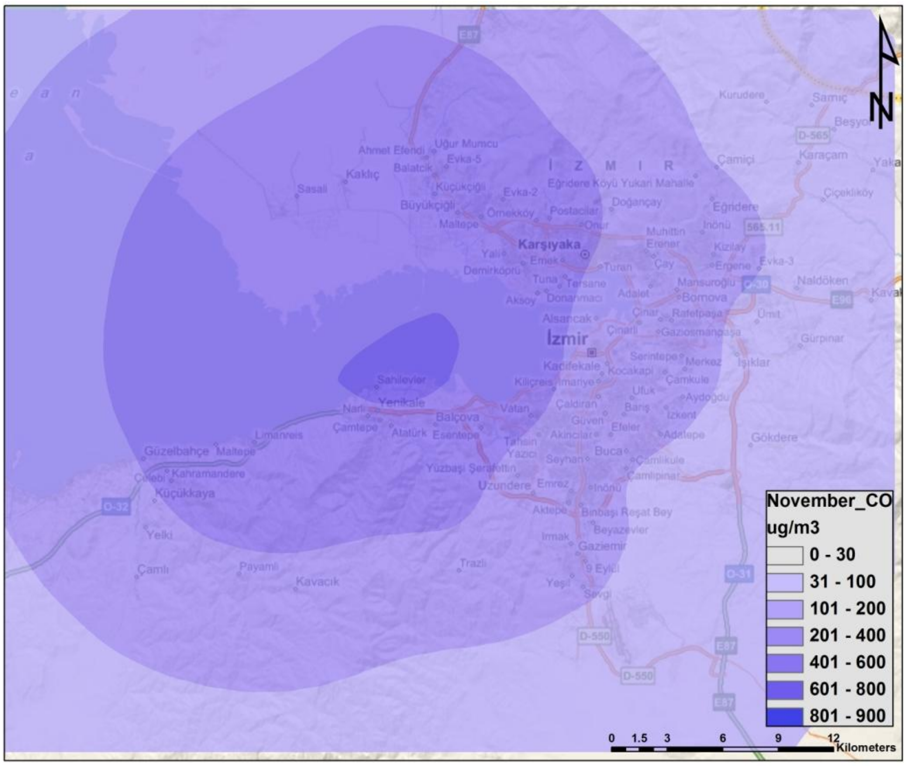


Figure 4.24 The monthly average CO concentrations in November (2008).

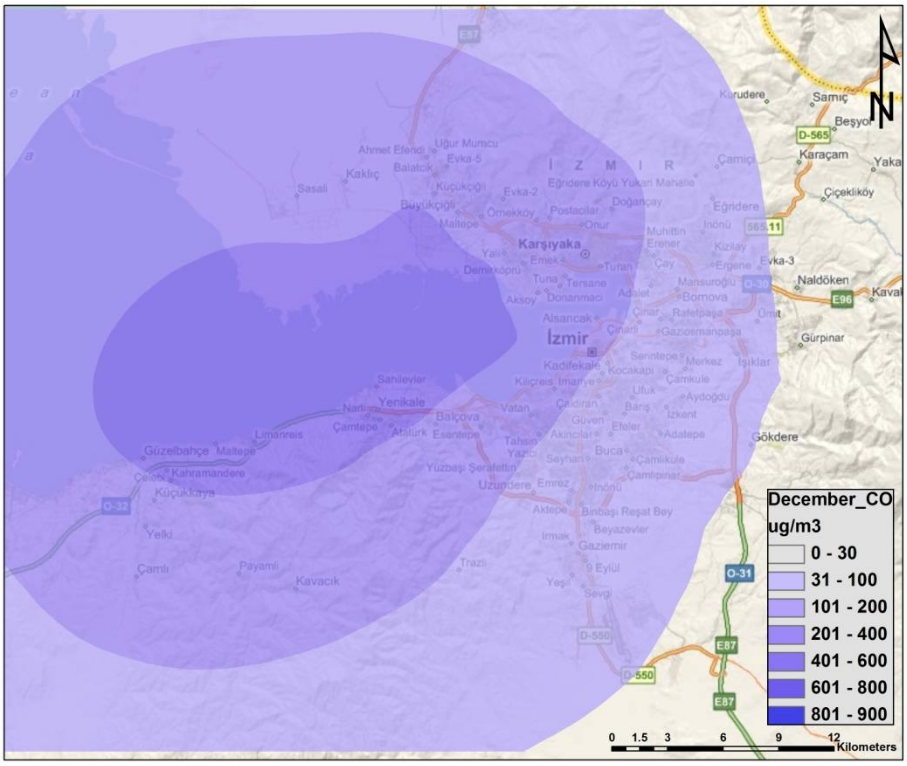


Figure 4.25 The monthly average CO concentrations in December (2008).

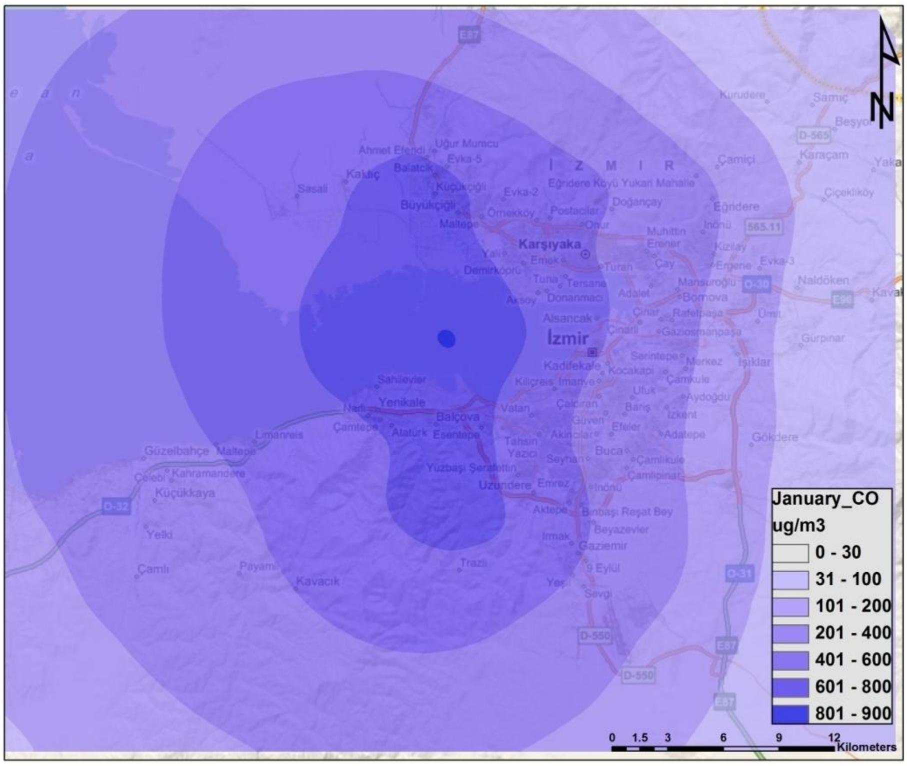


Figure 4.26 The monthly average CO concentrations in January (2009).

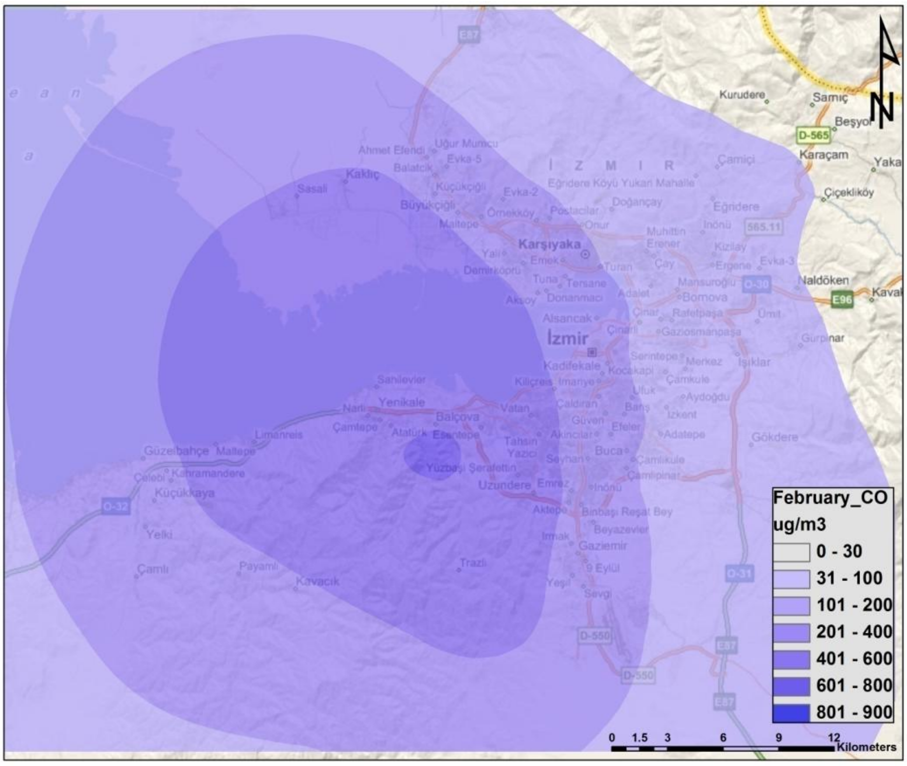


Figure 4.27 The monthly average CO concentrations in February (2009).

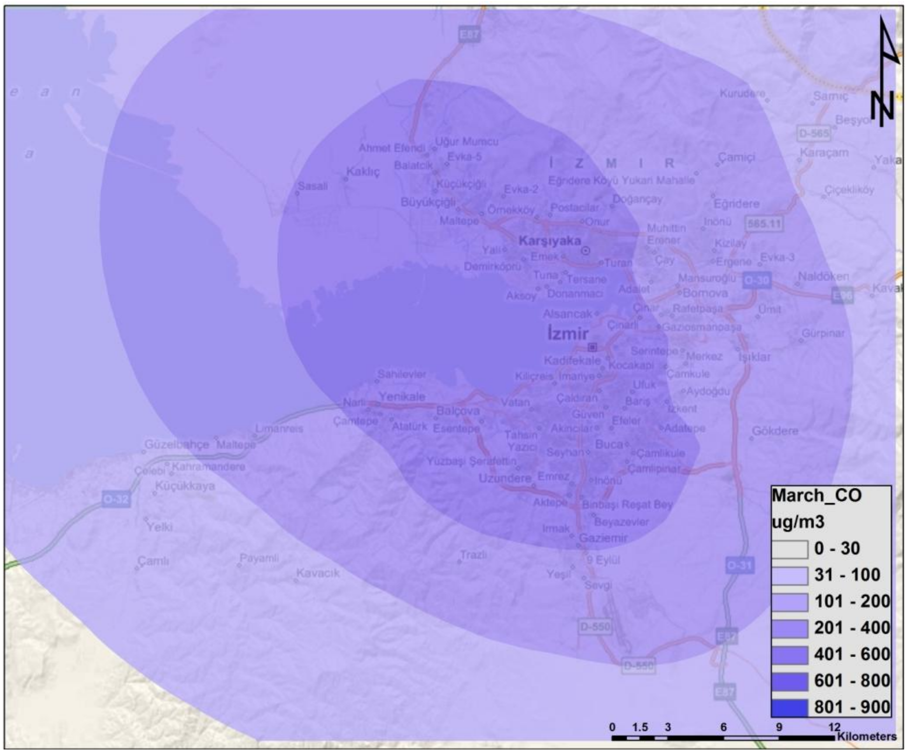


Figure 4.28 The monthly average CO concentrations in March (2009).

The maximum annual average concentration of VOC was approx. 47 μg/m^3 in winter. The maximum monthly VOC concentration in January was calculated as 86 μg/m^3. The maximum daily VOC concentration in 13 January 2009 was calculated as 648 μg/m^3. The maximum daily VOC concentration for this sampling day was higher than the daily limit value (2009) of 126 μg/m^3 according to the Air Quality Assessment and Management Regulations The maximum hourly VOC concentration in November, January and February was calculated as 805, 2073 and 784 μg/m^3. The maximum hourly VOC concentration for this sampling day was higher than the hourly limit value (2009) of 280 μg/m^3 according to the Air Quality Assessment and Management Regulations. The map of the winter months average VOC concentrations calculated by CALPUFF model is given in Figure 4.29-Figure 4.33. The highest daily concentrations and coordinates are given at Table 4.9.

Table 4.9 The highest daily VOC concentrations and coordinates at each month in 2008-09 winter.

Month	X(UTM)	Y(UTM)	VOC con	Year	Date
November	500780	4249647	216	2008	26
December	492780	4247647	133	2008	6
January	506780	4243647	648	2009	13
February	502780	4247647	304	2009	3
March	504780	4263647	189	2009	30

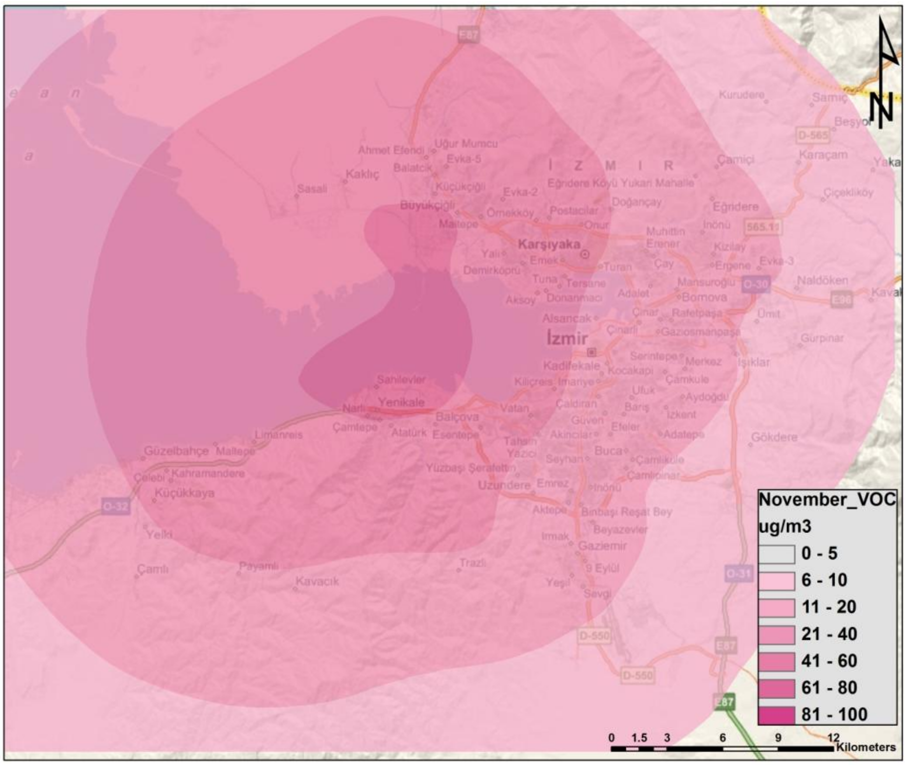


Figure 4.29 The monthly average VOC concentrations in November (2008).

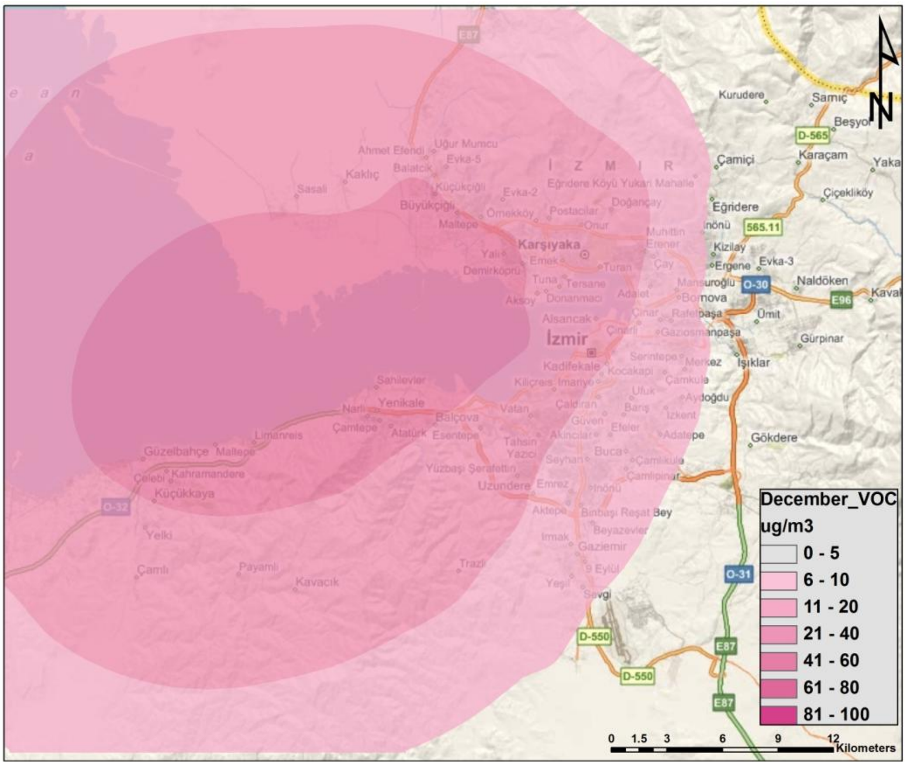


Figure 4.30 The monthly average VOC concentrations in December (2008).

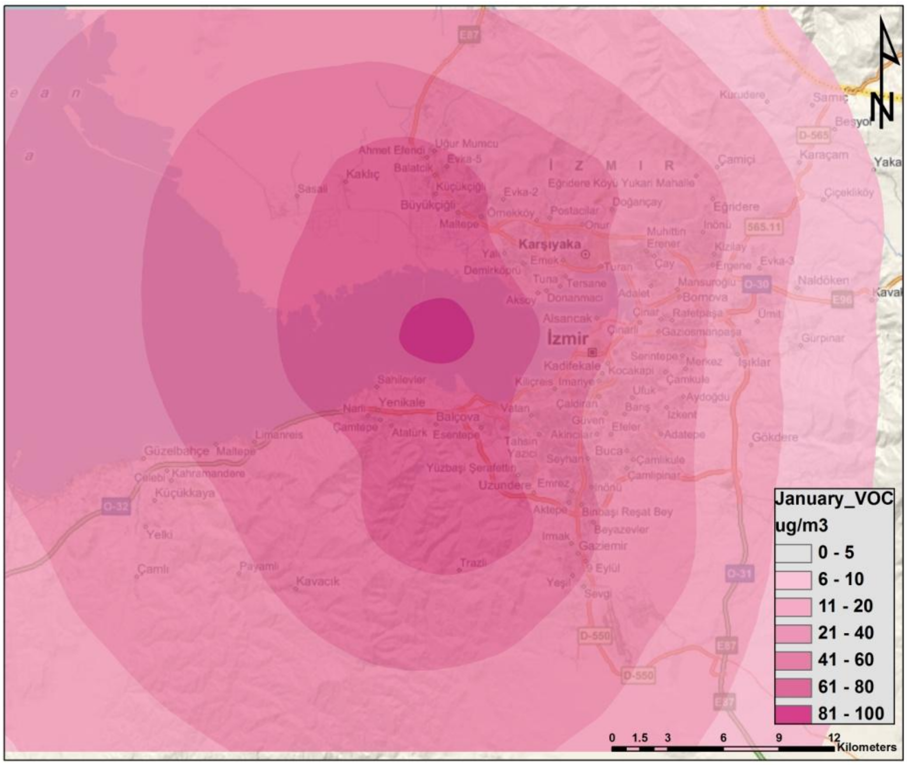


Figure 4.31 The monthly average VOC concentrations in January (2009).

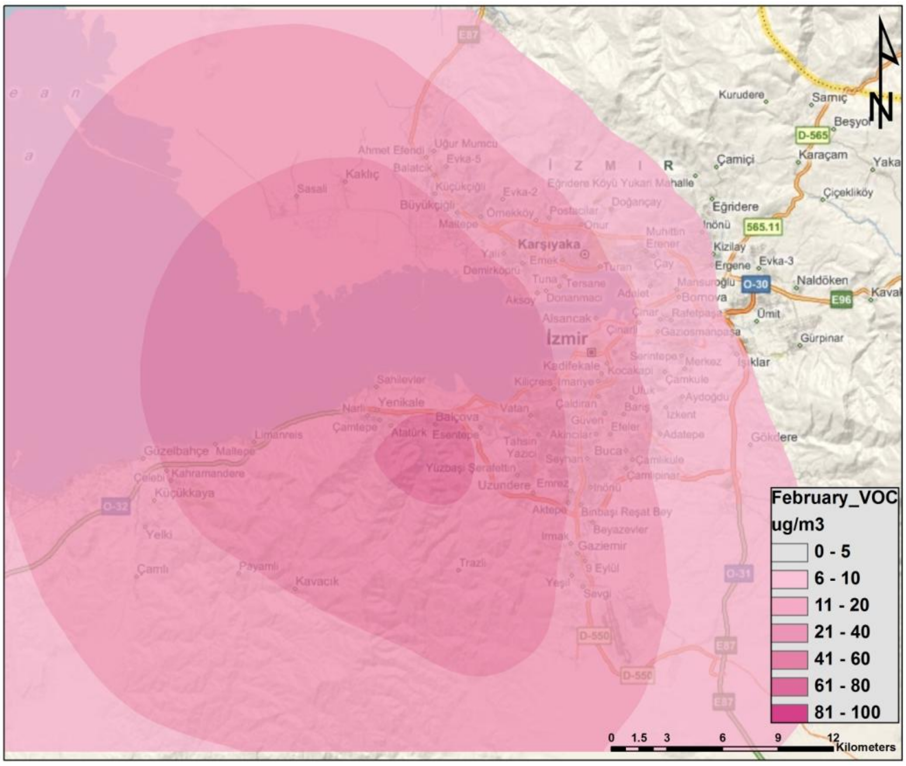


Figure 4.32 The monthly average VOC concentrations in February (2009).

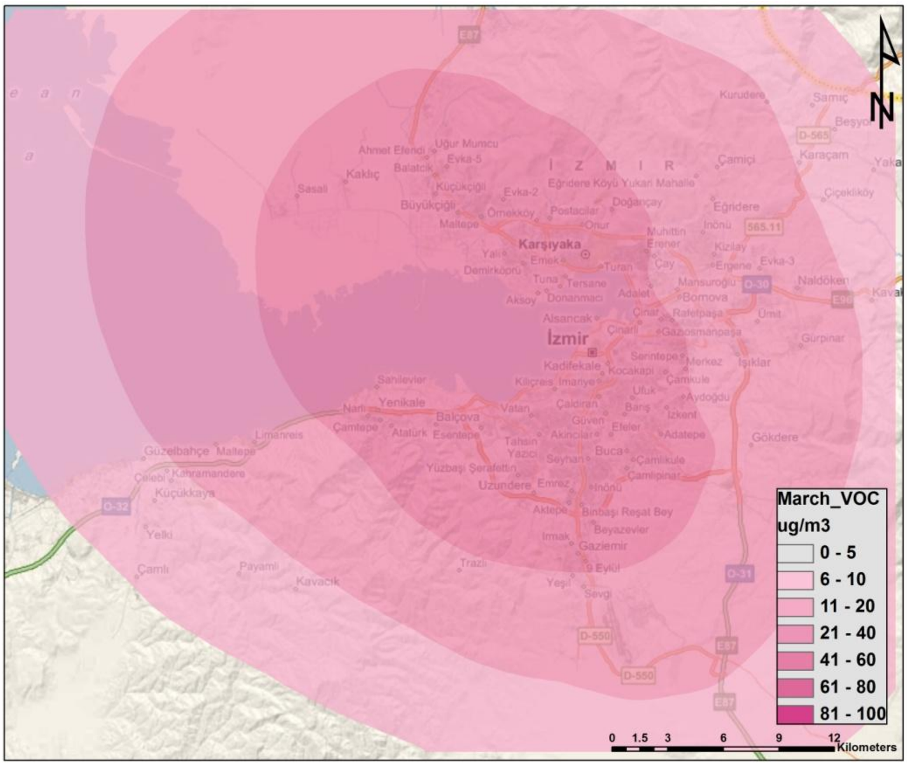


Figure 4.33 The monthly average VOC concentrations in March (2009)

The maximum daily concentrations were calculated on 13 January 2009 when inversion thickness was measured as 288 meter. The beginning elevation of inversion was 41 m. The severity of inversion was estimated with using meteorological data as 55, or namely middling inversion.

4.3 Air Quality in İzmir

Air quality of İzmir measured in seven ambient air quality monitoring stations located at various sites in the city considering their topography. The hourly average concentrations monitored at seven ambient air quality stations from November 2008 to March 2009 were given for SO_2 and PM_{10} between Figure 4.34 to Figure 4.46. Alsancak Station automatically measures CO, NO_2, SO_2, PM_{10} and O_3. But in this study only SO_2 and PM_{10} records were used. Because the other stations haven't got CO, NO_2 and O_3 monitoring systems.

The highest hourly average concentration of SO_2 and PM_{10} recorded were 340 μg/m^3 at 28.03.2009 and 429.3 μg/m^3 at 15.01.2009 respectively at Alsancak station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.34 and in Figure 4.35. The total averages of SO_2 and PM_{10} in winter mounts were 31.4 μg/m^3 and 67.4 μg/m^3 in Alsancak.

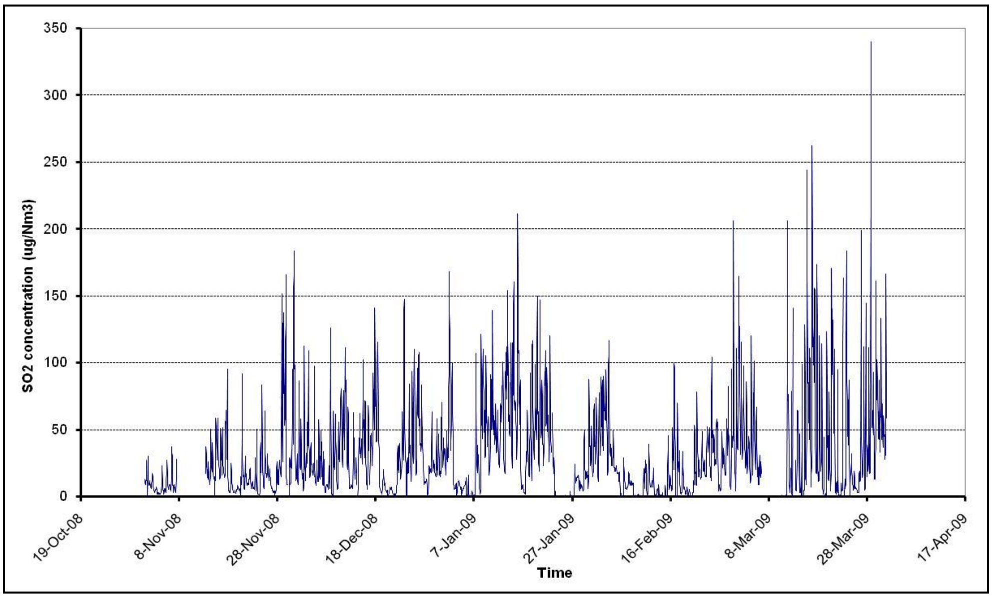


Figure 4.34 SO_2 concentrations of Alsancak Station in 2008-09 winter season.

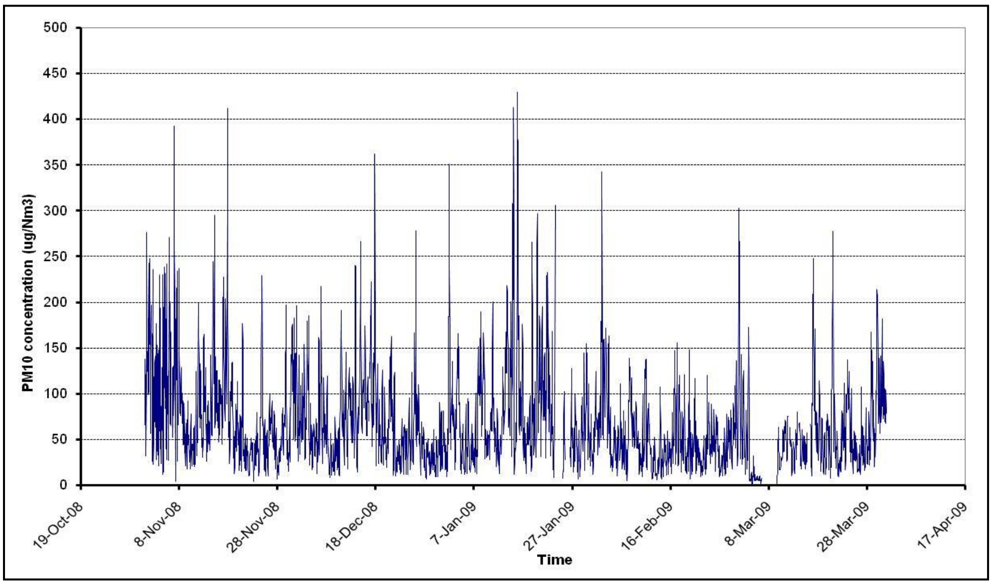


Figure 4.35 PM_{10} concentrations of Alsancak Station in 2008-09 winter season.

The highest hourly average concentration of PM_{10} and SO_2 recorded were 562.1 µg/m^3 at 15.01.2009 and 196.2 µg/m^3 at 04.03.2009 respectively at Şirinyer station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.36 and Figure 4.37. The total averages of SO_2 and PM_{10} in winter mounts were 14.8 µg/m^3 and 82.9 µg/m^3 in Şirinyer.

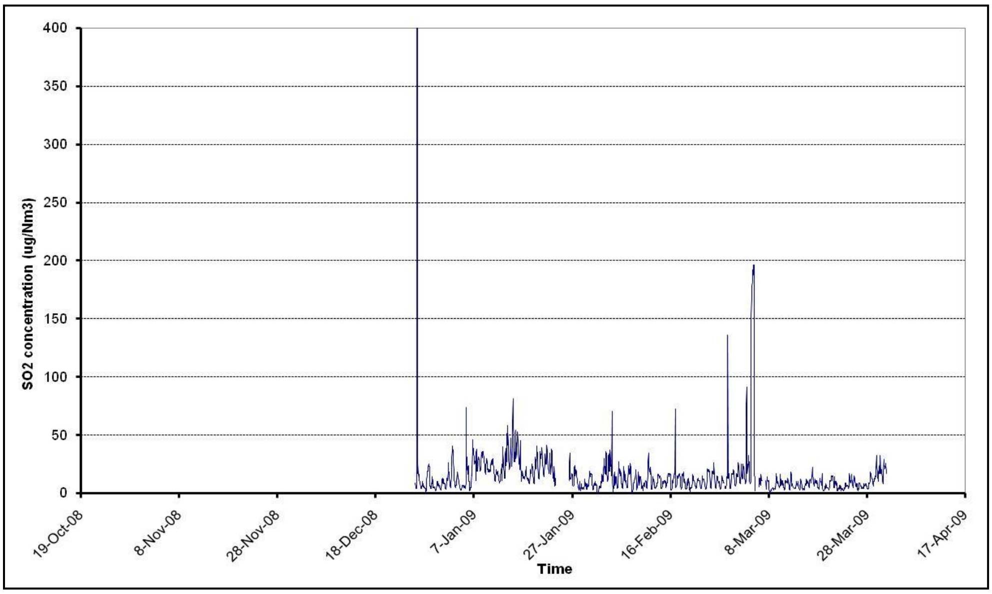


Figure 4.36 SO_2 concentrations of Şirinyer Station in 2008-09 winter season.

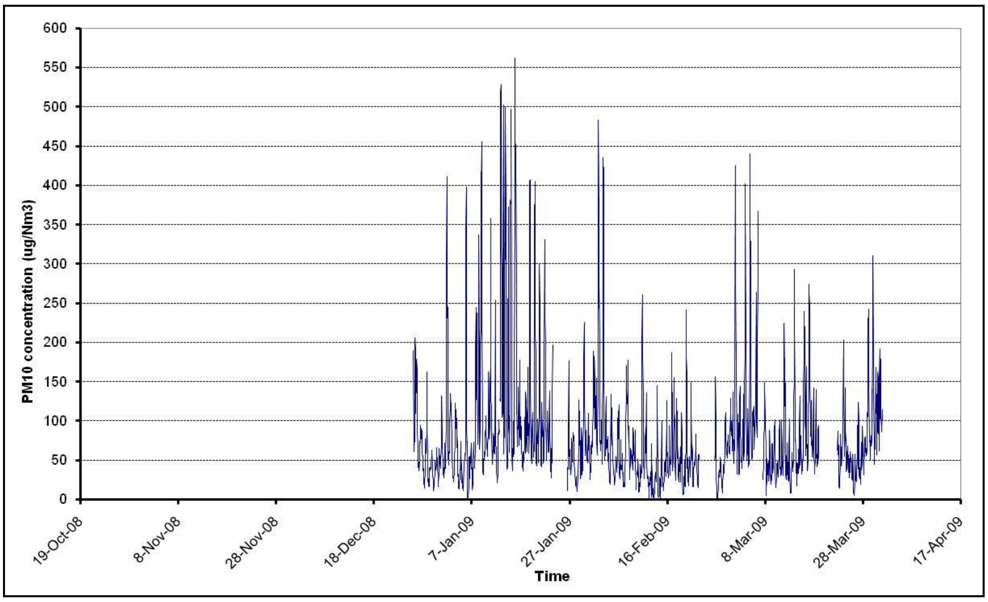


Figure 4.37 PM_{10} concentrations of Şirinyer Station in 2008-09 winter season.

The highest hourly average concentration of SO_2 and PM_{10} recorded were 439.5 μg/m^3 at 14.01.2009 and 437.8 μg/m^3 at 12.01.2009 respectively at Karşıyaka station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.38 and in Figure 4.39. The total averages of SO_2 and PM_{10} in winter mounts were 15.4 μg/m^3 and 52.8 μg/m^3 in Karşıyaka.

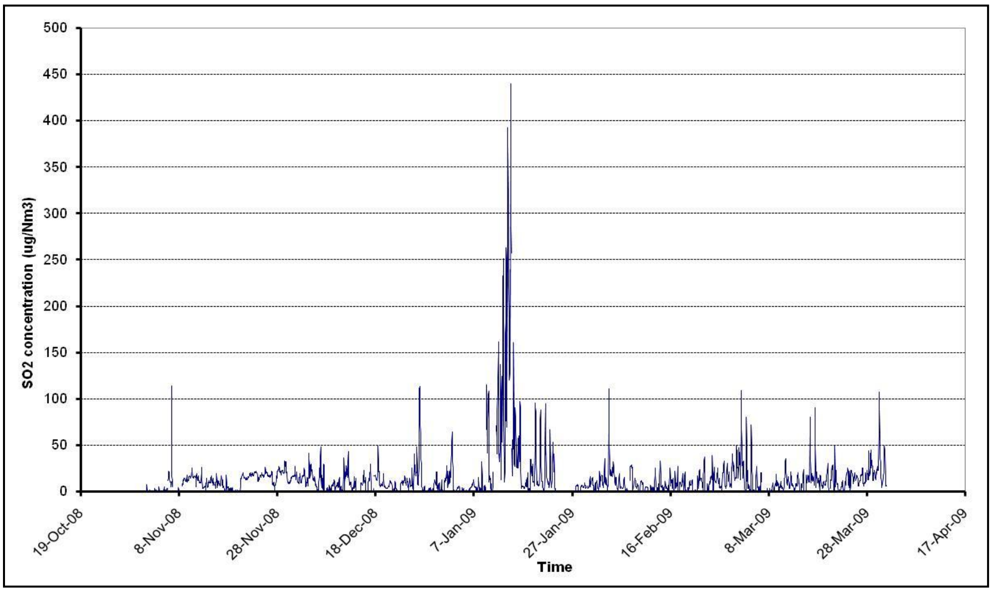


Figure 4.38 SO_2 concentrations of Karşıyaka Station in 2008-09 winter season.

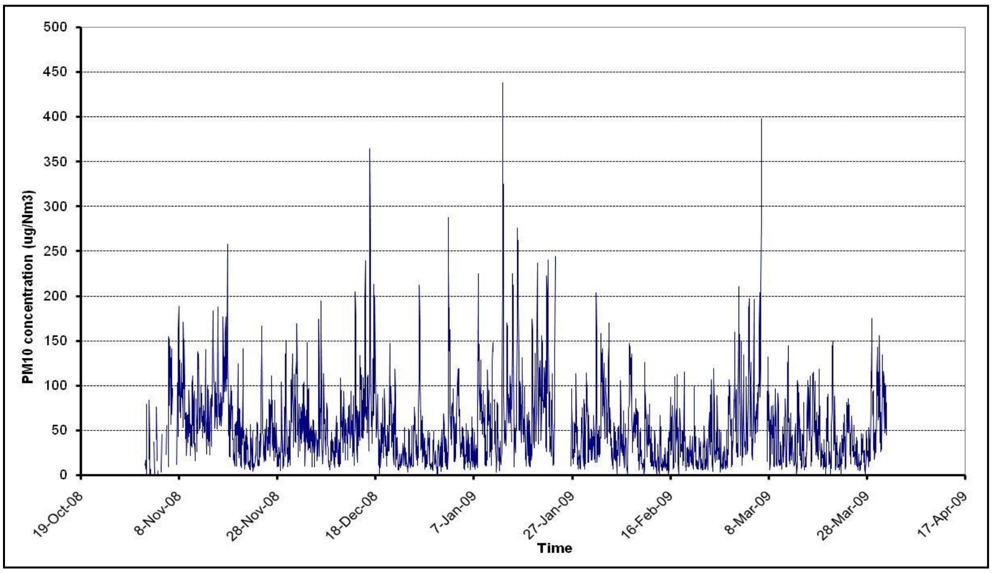


Figure 4.39 PM_{10} concentrations of Karşıyaka Station in 2008-09 winter season.

The highest hourly average concentration of SO_2 and PM_{10} recorded were 227.1 µg/m^3 at 11.12.2008 and 778.4 µg/m^3 at 06.03.2009 respectively at Güzelyalı station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.40 and Figure 4.41. The total averages of SO_2 and PM_{10} in winter mounts were 16.8 µg/m^3 and 61.8 µg/m^3 in Güzelyalı.

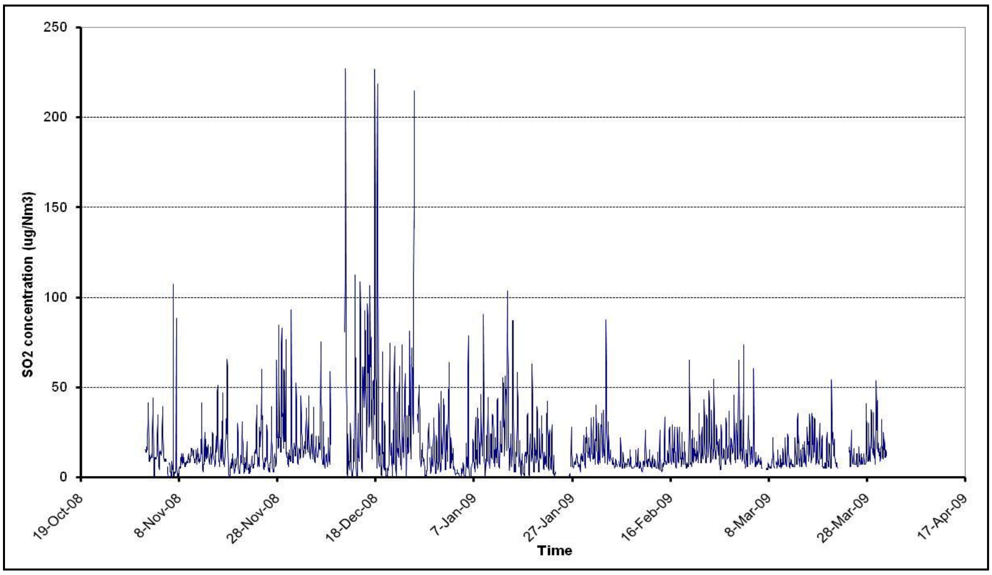


Figure 4.40 SO_2 concentrations of Güzelyalı Station in 2008-09 winter season.

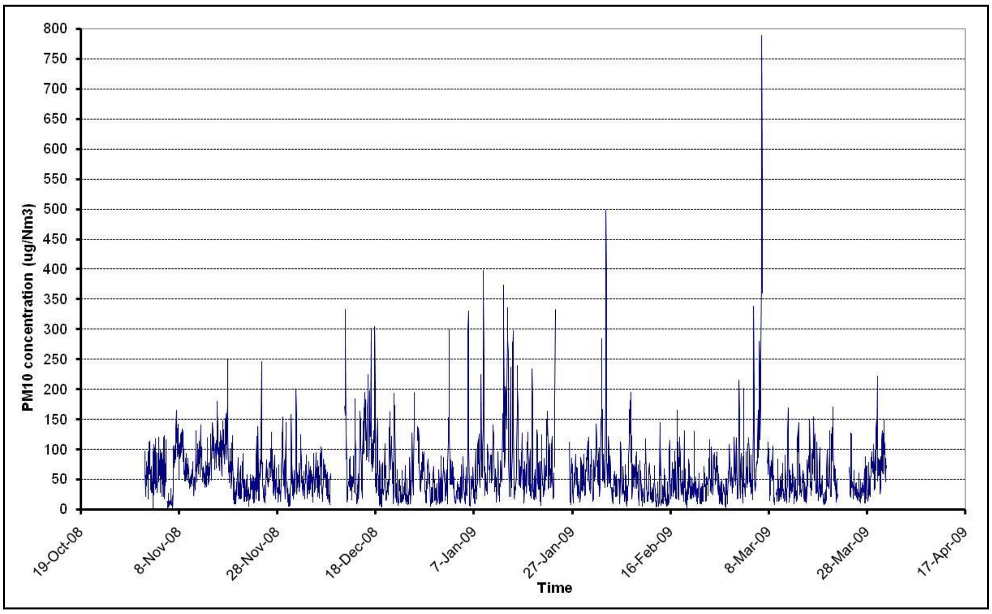


Figure 4.41 PM_{10} concentrations of Güzelyalı Station in 2008-09 winter season.

The highest hourly average concentration of SO_2 and PM_{10} recorded were 125.5 μg/m^3 at 18.12.2008 and 485.9 μg/m^3 at 06.03.2009 respectively at Bornova station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.42 and Figure 4.43. The total averages of SO_2 and PM_{10} in winter mounts were 7.6 μg/m^3 and 37.4 μg/m^3 in Bornova.

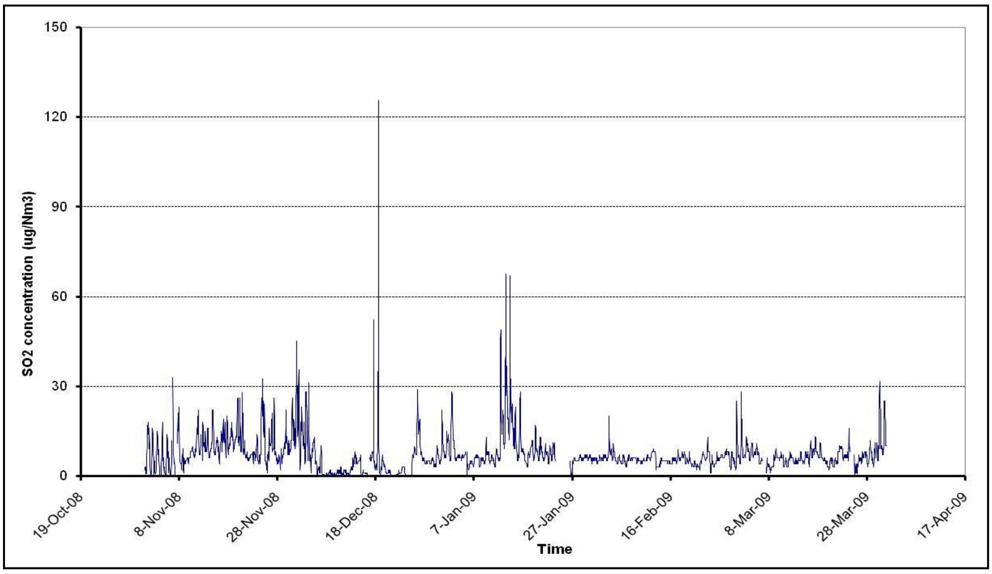


Figure 4.42 SO_2 concentrations of Bornova Station in 2008-09 winter season.

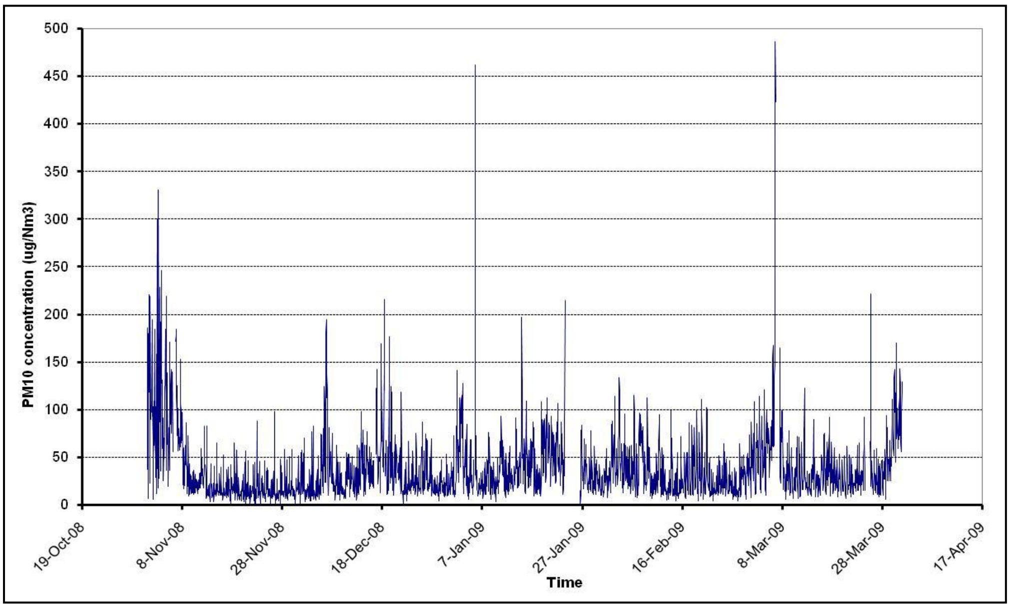


Figure 4.43 PM_{10} concentrations of Bornova Station in 2008-09 winter season.

The highest hourly average concentration of SO_2 and PM_{10} recorded were 282.9 µg/m^3 at 27.12.2008 and 774 µg/m^3 at 23.01.2009 respectively at Çiğli station. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.44 and Figure 4.45. The total averages of SO_2 and PM_{10} in winter mounts were 6.9 µg/m^3 and 71.7 µg/m^3 in Çiğli.

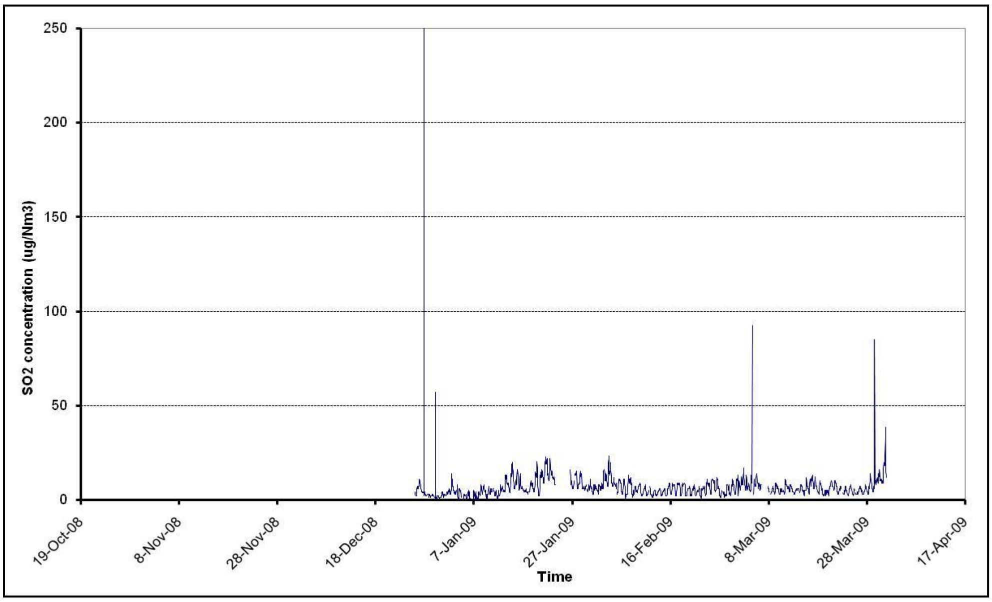


Figure 4.44 SO_2 concentrations of Çiğli Station in 2008-09 winter season.

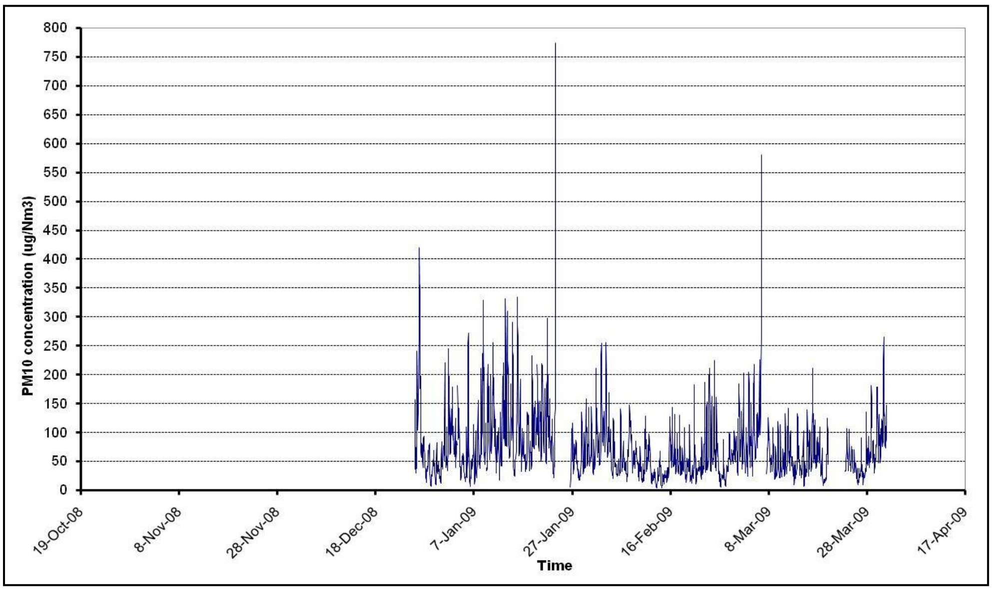


Figure 4.45 PM_{10} concentrations of Çiğli Station in 2008-09 winter season.

The highest hourly average concentration of SO_2 recorded were 322.4 µg/m^3 at 06.03.2009 respectively at Gaziemir station. While the PM10 monitoring system was broken down, there was no available PM_{10} data. The hourly average concentrations at this station from November 2008 to March 2009 were summarized in Figure 4.46. The total average of SO_2 in winter mounts was 6.4 µg/m^3 in Gaziemir.

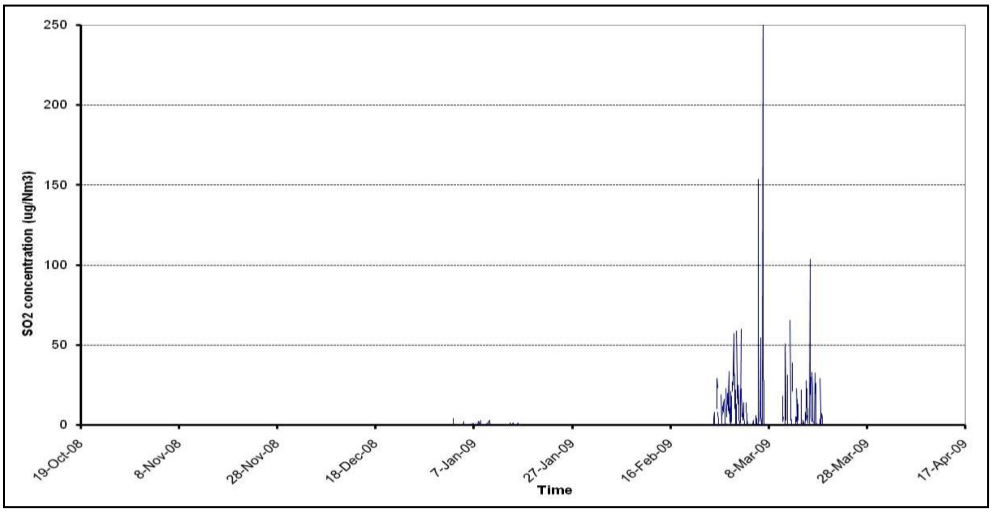
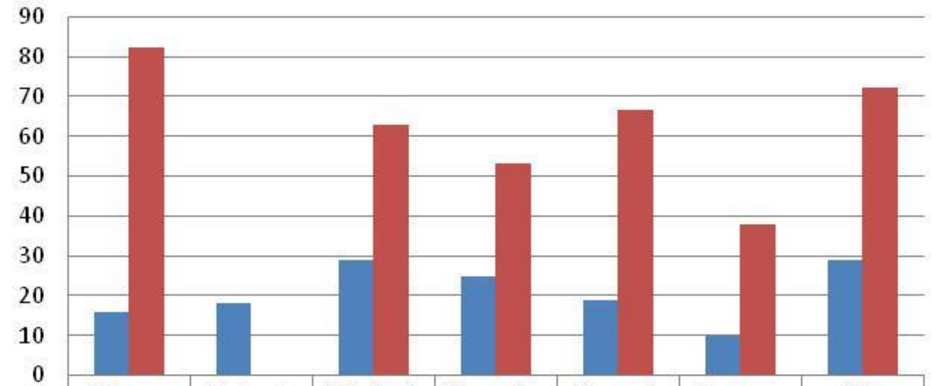


Figure 4.46 SO_2 concentrations of Gaziemir Station in 2008-09 winter season.

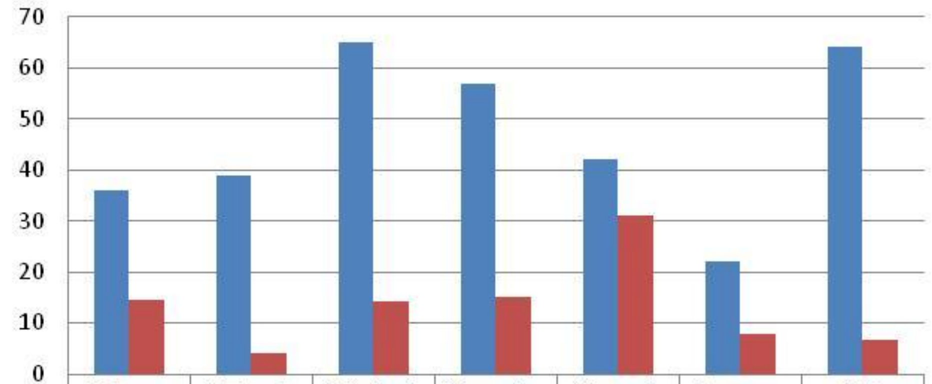
4.4 Model Evaluation

Average predicted and monitored annual concentrations at 7 stations for 2008-09 winter season were compared to evaluate for the level of representativeness of the model predictions. The simple comparisons of annual avarage predicted and measured PM_{10} and SO_2 concentrations were given in Figure 4.47 and in Figure 4.48. The results showed that the overall performance of PM_{10} predictions was better than SO_2. In this study, the contribution of domestic heating to air quality of İzmir was determined in 2008-2009’s winter. Namely, the contribution of industrial and traffic emissions weren’t included the result of the emission inventory. So the predicted concentrations must be lower than measured data. The predicted concentrations of PM_{10} were lower than the monitored PM_{10} concentrations in all stations. On the contrary the predicted concentrations of SO_2 were higher than measured SO_2 concentrations.



	Şirinyer	Gaziemir	Güzelyalı	Karşıyaka	Alsancak	Bornova	Çiğli
Predicted	16	18	29	25	19	10	29
Observed	82		63	53	66	38	72

Figure 4.47 Comparison of predicted and measured annual average PM_{10} concentrations in 2008-09 winter season.



	Şirinyer	Gaziemir	Güzelyalı	Karşıyaka	Alsancak	Bornova	Çiğli
Predicted	36	39	65	57	42	22	64
Observed	15	4	14	15	31	8	7

Figure 4.48 Comparison of predicted and measured annual average SO_2 concentrations in 2008-09 winter season.

The reason of low accuracy might be the uncertainty of the predictions and observations. The uncertainty of the predictions can arise from the emission calculations and dispersion modeling. The causes of uncertainty in the model results come from different sources: natural meteorological variations, approximations in the model formulation; estimations in deriving data to input; and unfairness due to the aims and limitations of the model. In addition, the major uncertainity factor was to assume the residential areas like as area sources. Emissions from area sources are assumed to be of neutral buoyancy in air dispersion modeling. For that reason, plume phenomena such as downwash and impaction on elevated terrain features are not thinking about relevant for modeling area source.

The uncertainty of air quality measurements at the monitoring stations as well as the unsuitable geographical locations of the stations might be significant factors for not getting a higher relevance between predictions and actual measurements. The sources of uncertainties can be categorised into parameter uncertainty, model uncertainty, scenario uncertainty and evaluation data uncertainty.

CHAPTER FIVE
CONCLUSION

In this study the contribution of emissions from domestic heating to air quality of İzmir in 2008-2009's winter was investigated. The results showed that Konak was the most polluting district in the city center of İzmir contributing to about 18.3% of total SO_2 emissions, 18.3% of PM_{10} emissions, 17.4% of total NO_2 emissions, 18.3% of total VOC emissions and 18.3% of total CO emissions. Nearly 9700 tons SO_2, 1250 tons NO_2, 4350 tons PM_{10}, 49700 tons CO and 5200 tons VOC were released to atmosphere from the city center of İzmir in 2008-09 winter season. In conclusion of this comparison with Clean Air Plan of 2000, it is observed that especially SO_2 and PM_{10} values were decreased almost 80%. The most important fact was decreasing of coal consumption because of usage of natural gas for domestic heating. When winter emissions originated from urban traffic and domestic heating sources were compared, it was seen that the emissions of domestic heating sources were higher than traffic emissions which were quoted from a research project of DEU.

Greenhouse gases emissions of study area for domestic heating were 1603465 tons/year CO_2, 17 tons/year N_2O and 2027 tons/year CH_4 according to the calculations made by using USEPA's emission factors, 2250018 tons/year CO_2, 33 tons/year N_2O and 10427 tons/year CH_4 according to the calculations made by using CORINAIR's emission factors and 2264046 tons/year CO_2, 35 tons/year N_2O and 6956 tons/year CH_4 according to the calculations made by using IPCC's emission factors in 2008-09 winter season. When the three methods were compared, emission factor of IPCC were higher than of USEPA and CORINAIR. According to 2008 national inventory reports and tables of Turkey 48223916 tons CO_2, 1264 tons N_2O and 146350 tons CH_4 reached to atmosphere from residential in 2008. İzmir is contributing with about 5% of total greenhouse gases emissions like as total population of Turkey.

According to model results, the monthly average concentrations were found higher around Gulf of İzmir in 2008-2009 winter season. The results showed that the most affected residential areas were Balçova, Karabağlar, Konak and Karşıyaka which are central districts in the city center from domestic heating emissions due to their dense population. Outputs of the model showed that the eastern part of the city was the less polluted than other areas.

Although daily average concentrations observed at monitoring stations generally did not exceed the daily limits, but the predicted concentrations in these coordinates exceeded the limit values from time to time. The maximum daily average concentrations were predicted on 13/01/2009. Air pollution episodes generally occur on two or three consecutive days which are dangerous for human health due to meteorological conditions in İzmir. The maximum hourly average concentrations were measured at Alsancak, Şirinyer and Karşıyaka on from 11.01.2009 to 15.01.2009. It is shown that the most polluted regions can be shifted daily due to meteorological conditions. The highest hourly average concentration of SO_2 and PM_{10} recorded were 439.5 μg/m^3 (14.01.2009) and 437.8 μg/m^3 (12.01.2009) respectively at Karşıyaka station. While the one of the most polluted regions was Şirinyer having the maximum hourly PM_{10} concentration of 562.1 μg/m^3, the other one was Alsancak having hourly PM_{10} concentration of 429.3 μg/m^3 on 15 January 2009.

The simple comparisons of annual predicted and measured average daily PM_{10} and SO_2 concentrations showed that the overall performance of PM_{10} predictions is better than SO_2. Since only the contribution of domestic heating to air quality of İzmir was calculated, the predicted concentrations must be lower than observation data. But while the predictions of PM_{10} were lesser than the monitored PM_{10} concentrations, the predictions of SO_2 were higher than measured SO_2 concentrations. The reason of low accuracy might be the uncertainty of the predictions and obsevations. The uncertainty of the predictions can arise from the emission calculations and dispersion modeling. The uncertainty of air quality measurements at the monitoring stations as well as the unsuitable geographical locations or deficient operation conditions. It is necessary that more ambient air quality monitoring stations and the number of pollutant parameters measured should be increased for better comparison of predicted and observed concentrations.

In literature survey conducted within the context of this study, no previous study has been encountered related to district scale inventories of emissions covering domestic heating sources for city center of İzmir. This study should also be upgraded by means of higher quality data, whenever possible the determination air quality from domestic heating. In order to acquire more reliable data, it is important to determine conveniently the type and quantity of fuel type consumed. Periodical controls conducted by responsible authorities are also required. Furthermore, when specifically İzmir considered, use of electricity for heating purposes has become another option for residents, and consumption rates must be surveyed.

EU Directives (Council Directive 96/62/EF, 99/30/EC, 2000/69/EC, 2002/3/EC and 2004/107/EC) require monitoring and assessment of air quality by preparing clean air plan in large cities with more than 250000 inhabitants. Although the policies of Turkish urban air quality management generally consider monitoring systems, comprehensive emission inventories, mapping of air quality and action plans are so poorly and not up to date. The most recent study for this purpose was İzmir Clean Air Plan in 2000 (Müezzinoğlu et.al., 2000). So emission inventories of İzmir should be updated and be checked regularly for future projects. The results of this study can be a part of the emission inventory which will be prepared in the future. Meanwhile this study can be base on the preparation of clean air plan about domestic heating in residential areas.

This study should also be upgraded by means of higher quality data such as the determination air quality from domestic heating and be developed with adding the emissions of other air pollution sources as industrial, traffic or natural.

According to the results of this study, İzmir Metropolitan Municipality can prepare an action plan for decreasing effects of domestic heating, hence will be able to have a better air quality in future. To prevent the negative effects of air pollution, high quality coal which has lower sulfur and ash content has to be used and use of the natural gas, geothermal or solar energy must be supported in the suitable region. In addition all present outputs of this study such as the results and maps of emission inventory with air quality modeling can be used to determine the locations and estimate the effects of the new residential areas that will be established in the city.

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APPENDIX-A

List of Tables

Page

APPENDIX-B

List of Figures

Page

APPENDIX-C

The Results of Emission Inventory

BALÇOVA

Total emissions and fuel consumption of the districts of Balçova in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Bahçelerarası	No Use of Natural Gas	261	2.8	0.3	1.3	14.5	1.5
Çetin Emeç		4265	46.4	5.7	20.9	237.5	25.0
Eğitim		4926	53.6	6.6	24.1	274.3	28.9
Fevzi Ç.*		-	0.0	0.0	0.0	0.0	0.0
İnciraltı*		-	0.0	0.0	0.0	0.0	0.0
Korutürk*		-	0.0	0.0	0.0	0.0	0.0
Onur*		-	0.0	0.0	0.0	0.0	0.0
Telefrik*		3295	35.9	4.4	16.1	183.5	19.3
Total		**-**	**138.8**	**17.0**	**62.3**	**709.9**	**74.7**

* Geothermal energy is used for domestic heating in these quarters.

The amount of emissions in Balçova per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	138.8	9.1	0.005
NO_X	16.9	1.1	0.001
PM_{10}	62.3	4.1	0.002
CO	709.9	46.3	0.023
VOC	74.7	4.9	0.002

BAYRAKLI

Total emissions and fuel consumption of the districts of Bayraklı in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Adalet	193416	5064	55.2	7.1	24.8	282.2	29.7
Alpaslan	-	3429	37.3	4.6	16.8	191.0	20.1
Bayraklı	-	2474	26.9	3.3	12.1	137.8	14.5
Cengizhan	-	4442	48.4	5.9	21.7	247.4	26.0
Çay	-	2713	29.5	3.6	13.3	151.1	15.9
Çiçek	-	4392	47.8	5.8	21.5	244.6	25.7
Doğançay	-	783	8.5	1.0	3.8	43.6	4.6
Emek	-	4540	49.4	6.0	22.2	252.8	26.6
Fuat Edip B.	-	4481	48.8	6.0	21.9	249.5	26.3
Gümüşpala	-	5700	62.1	7.6	27.9	317.4	33.4
Manavkuyu	1666432	7907	86.1	13.6	38.7	442.0	46.8
Mansuroğlu	1397694	5829	63.5	10.3	28.5	326.0	34.5
Muhittin E.	-	3019	32.9	4.0	14.8	168.1	17.7
Onur	-	4219	45.9	5.6	20.6	235.0	24.7
Org. Nafiz G.	-	4683	51.0	6.2	22.9	260.8	27.4
Osmangazi	229024	6852	74.6	9.5	33.5	381.8	40.2
Postacılar	-	3390	36.9	4.5	16.6	188.8	19.9
R. Şevket İnce	-	4238	46.2	5.6	20.7	236.0	24.8
Soğukkuyu M.	-	2775	30.2	3.7	13.6	154.5	16.3
Tepekule	124469	4734	51.6	6.5	23.2	263.8	27.8
Turan	-	61	0.7	0.1	0.3	3.4	0.4
Yamanlar	-	5050	55.0	6.7	24.7	281.2	29.6
75.Yıl	-	1191	13.0	1.6	5.8	66.3	7.0
Total	**3611035**	**91966**	**1001.6**	**129.0**	**449.8**	**5125.2**	**539.9**

The amount of emissions in Bayraklı per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km²**	**tons/year/house**
SO_2	1001.6	44.0	0.010
NO_2	129.0	5.7	0.001
PM_{10}	449.8	19.8	0.004
CO	5125.2	225.1	0.051
VOC	539.9	23.7	0.005

BORNOVA

Total emissions and fuel consumption of the districts of Bornova in 2008-09 winter season

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Atatürk	3922	9205	100,2	12,2	45,0	512,6	53,9
Barbaros	-	4506	49,1	6,0	22,0	250,9	26,4
Beşyol	-	124	1,4	0,2	0,6	6,9	0,7
Birlik	-	2715	29,6	3,6	13,3	151,2	15,9
Çamiçi	-	97	1,1	0,1	0,5	5,4	0,6
Çamkule	-	1605	17,5	2,1	7,8	89,4	9,4
Çınar	-	1902	20,7	2,5	9,3	105,9	11,1
Çiçekli	-	195	2,1	0,3	1,0	10,9	1,1
Doğanlar	-	5091	55,4	6,8	24,9	283,5	29,8
Egemenlik	-	844	9,2	1,1	4,1	47,0	4,9
Eğridere	-	287	3,1	0,4	1,4	16,0	1,7
Ergene	347038	3735	40,7	5,5	18,3	208,3	22,0
Erzene	2171634	6622	72,1	12,0	32,4	370,5	39,3
Evka-3	1703888	4691	51,1	8,8	23,0	262,6	27,9
Evka-4	234543	5201	56,6	7,3	25,4	289,8	30,5
GaziOsmanP.	-	5167	56,3	6,9	25,3	287,8	30,3
Gökdere	-	193	2,1	0,3	0,9	10,7	1,1
Gürpınar	-	2778	30,3	3,7	13,6	154,7	16,3
Işıklar	-	799	8,7	1,1	3,9	44,5	4,7
İnönü	-	8018	87,3	10,7	39,2	446,5	47,0
Karacaoğlan	-	1891	20,6	2,5	9,2	105,3	11,1
Karaçam	-	222	2,4	0,3	1,1	12,4	1,3
Kavaklıdere	-	836	9,1	1,1	4,1	46,6	4,9
Kayadibi	-	77	0,8	0,1	0,4	4,3	0,5
Kazımdirik	1860283	8935	97,3	14,7	43,7	499,1	52,8
Kemalpaşa	-	3006	32,7	4,0	14,7	167,4	17,6
Kızılay	-	5143	56,0	6,8	25,1	286,4	30,1
Koşukavak	-	2985	32,5	4,0	14,6	166,2	17,5
Kurudere	-	23	0,3	0,0	0,1	1,3	0,1
Laka	-	123	1,3	0,2	0,6	6,8	0,7
Meriç	-	3290	35,8	4,4	16,1	183,2	19,3
Merkez	-	2071	22,6	2,8	10,1	115,3	12,1
Mevlana	-	5509	60,0	7,3	26,9	306,8	32,3
Naldöken	-	1942	21,1	2,6	9,5	108,1	11,4
Rafetpaşa	-	6305	68,7	8,4	30,8	351,1	36,9
Sarnıçköy	-	90	1,0	0,1	0,4	5,0	0,5
Serintepe	-	2795	30,4	3,7	13,7	155,7	16,4
Tuna	-	2688	29,3	3,6	13,1	149,7	15,8
Ümit	-	1218	13,3	1,6	6,0	67,8	7,1
Yakaköy	-	668	7,3	0,9	3,3	37,2	3,9
Yeşilçam	-	1103	12,0	1,5	5,4	61,4	6,5
Yeşilova	-	8659	94,3	11,5	42,3	482,2	50,7
Yıldırım B.	-	2724	29,7	3,6	13,3	151,7	16,0
Yunus Emre	-	605	6,6	0,8	3,0	33,7	3,5
Zafer	-	4193	45,7	5,6	20,5	233,5	24,6
Total	**6321308**	**130876**	**1425,3**	**183,4**	**640,1**	**7293,6**	**768,3**

The amount of emissions in Bornova per area and household.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	1425.3	8.1	0.010
NO_2	183.4	1.0	0.001
PM_{10}	640.1	3.6	0.005
CO	7293.6	41.4	0.052
VOC	768.3	4.4	0.005

BUCA

Total emissions and fuel consumption of the districts of Buca in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Adatepe	18427	3982	43.4	5.3	19.5	221.8	23.3
Akıncılar	72802	3076	33.5	4.2	15.0	171.4	18.0
Atatürk	-	4695	51.1	6.2	23.0	261.5	27.5
Aydoğdu	-	442	4.8	0.6	2.2	24.6	2.6
Barış	407331	4006	43.6	6.1	19.6	223.5	23.6
Belenbaşı	-	452	4.9	0.6	2.2	25.2	2.6
Buca Koop	572661	3365	36.7	5.5	16.5	188.0	19.9
Cumhuriyet	61783	1409	15.3	2.0	6.9	78.5	8.3
Çağdaş	3739	936	10.2	1.3	4.6	52.1	5.5
Çaldıran	-	1185	12.9	1.6	5.8	66.0	6.9
Çamlık	32720	3502	38.1	4.7	17.1	195.1	20.5
Çamlıkule	1554	4759	52.0	6.4	23.3	265.8	28.0
Çamlıpınar	-	3295	35.9	4.4	16.1	183.5	19.3
Dicle	40508	1748	19.0	2.4	8.5	97.4	10.3
Doğancılar	-	138	1.5	0.2	0.7	7.7	0.8
Dumlupınar	563898	309	3.4	1.5	1.5	17.8	2.0
Efeler	-	6608	72.0	8.8	32.3	368.0	38.7
Fırat	59541	5584	60.8	7.5	27.3	311.0	32.7
Gaziler	-	1626	17.7	2.2	8.0	90.6	9.5
Göksu	76126	7584	82.6	10.2	37.1	422.4	44.5
Güven	19674	2128	23.2	2.9	10.4	118.5	12.5
Hürriyet	199058	3872	42.2	5.5	18.9	215.8	22.7
İnkılap	-	3367	36.7	4.5	16.5	187.5	19.7
İnönü	4480	4826	52.6	6.4	23.6	268.8	28.3
İz-Kent	-	2017	22.0	2.7	9.9	112.3	11.8
Karaağaç	11669	328	3.6	0.5	1.6	18.3	1.9
Karanfil	-	1597	17.4	2.1	7.8	88.9	9.4
Kaynaklar C.	-	730	7.9	1.0	3.6	40.7	4.3
Kaynaklar	-	486	5.3	0.6	2.4	27.1	2.8
Kırıklar	33401	205	2.2	0.3	1.0	11.5	1.2
Kozağaç	37639	5457	59.4	7.3	26.7	303.9	32.0
Kuruçeşme	22202	2983	32.5	4.0	14.6	166.1	17.5
Laleli	429464	1354	14.8	2.6	6.6	75.8	8.1
Menderes	-	4690	51.1	6.2	22.9	261.2	27.5
Murathan	-	1279	13.9	1.7	6.3	71.2	7.5
Mustafa K.	-	3521	38.3	4.7	17.2	196.1	20.6
Seyhan	16046	1069	11.6	1.5	5.2	59.5	6.3
Şirinkapı	-	1259	13.7	1.7	6.2	70.1	7.4
Ufuk	376947	5334	58.1	7.8	26.1	297.4	31.4
Valirahmibey	-	3578	39.0	4.8	17.5	199.3	21.0
Yaylacık_B.	332	4322	47.1	5.8	21.2	241.1	25.4
Yenigün	-	5254	57.2	7.0	25.7	292.6	30.8
Yeşilbağlar	71073	4722	51.4	6.4	23.1	263.0	27.7
Yıldızlar	-	136	1.5	0.2	0.7	7.6	0.8
Yiğitler	458857	4317	47.0	6.6	21.1	240.9	25.4
Zafer	-	367	4.0	0.5	1.8	20.4	2.2
Total	**3591932**	**127899**	**1393.1**	**176.8**	**625.6**	**7127.5**	**750.6**

The amount of emissions in Buca per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	1393.1	12.5	0.011
NO_2	176.8	1.6	0.001
PM_{10}	625.6	5.6	0.005
CO	7127.5	64.2	0.058
VOC	750.6	6.8	0.006

ÇİĞLİ

Total emissions and fuel consumption of the districts of Çiğli in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Ahmet T. K.	151690	2471	26.9	3.6	12.1	137.8	14.5
Atatürk	-	2476	27.0	3.3	12.1	137.9	14.5
Aydınlıkevler	191361	1026	11.2	1.7	5.0	57.3	6.1
Balatçık	-	2801	30.5	3.7	13.7	156.0	16.4
Çağdaş	190493	3484	37.9	5.0	17.0	194.2	20.5
Cumhuriyet	-	1968	21.4	2.6	9.6	109.6	11.5
Egekent	199779	2007	21.9	3.0	9.8	112.0	11.8
Esentepe	37613	586	6.4	0.8	2.9	32.7	3.4
Evka-2	5620	1725	18.8	2.3	8.4	96.1	10.1
Evka-5	96947	4579	49.9	6.3	22.4	255.1	26.9
Evka-6	18985	980	10.7	1.3	4.8	54.6	5.7
Güzeltepe	-	2275	24.8	3.0	11.1	126.7	13.3
Harmandalı Atatürk	-	308	3.4	0.4	1.5	17.2	1.8
İnönü	-	660	7.2	0.9	3.2	36.8	3.9
İstasyonaltı	1261156	5334	58.1	9.4	26.1	298.3	31.6
İzkent	186647	2265	24.7	3.4	11.1	126.3	13.3
Kaklıç	-	599	6.5	0.8	2.9	33.4	3.5
Köyiçi	-	2249	24.5	3.0	11.0	125.2	13.2
Küçük Çiğli	28117	4514	49.2	6.1	22.1	251.4	26.5
Maltepe	-	1414	15.4	1.9	6.9	78.7	8.3
Sasallı M.	-	1427	15.5	1.9	7.0	79.5	8.4
Şirintepe	-	3350	36.5	4.5	16.4	186.6	19.6
Uğur Mumcu	-	1062	11.6	1.4	5.2	59.1	6.2
Yakakent	-	2178	23.7	3.0	10.7	121.3	12.8
Yeni M.	-	2962	32.3	4.0	14.5	165.0	17.4
Total	**2368408**	**54700**	**595.7**	**77.3**	**267.5**	**3048.7**	**321.2**

The amount of emissions in Çiğli per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	595.7	9.1	0.010
NO_2	77.3	1.2	0.001
PM_{10}	267.5	4.1	0.004
CO	3048.7	46.4	0.051
VOC	321.2	4.9	0.005

GAZİEMİR

Total emissions and fuel consumption of the districts of Gaziemir in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Aktepe	-	2485	27.1	3.3	12.2	138.4	14.6
Atatürk	-	1790	19.5	2.4	8.8	99.7	10.5
Atıfbey	1129885	2269	24.7	5.1	11.1	127.5	13.6
Beyazevler	-	1178	12.8	1.6	5.8	65.6	6.9
Binbaşı R.	-	735	8.0	1.0	3.6	40.9	4.3
9 Eylül	176842	2023	22.0	3.0	9.9	112.8	11.9
Ermez	-	1835	20.0	2.4	9.0	102.2	10.8
Fatih	-	725	7.9	1.0	3.5	40.4	4.2
Gazi	604249	1989	21.7	3.8	9.7	111.4	11.8
Gazikent	533024	1369	14.9	2.8	6.7	76.8	8.2
Hürriyet	-	3518	38.3	4.7	17.2	195.9	20.6
Irmak	257444	2182	23.8	3.4	10.7	121.8	12.9
Menderes	-	2175	23.7	2.9	10.6	121.1	12.7
Sevgi	915907	1738	18.9	4.0	8.5	97.7	10.4
Yeşil	335735	1492	16.3	2.6	7.3	83.4	8.8
Zafer	118921	1094	11.9	1.7	5.4	61.0	6.4
Total	**4072007**	**28597**	**311.5**	**45.6**	**139.9**	**1596.7**	**168.7**

The amount of emissions in Gaziemir per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	tons/year/km^2	tons/year/house
SO_2	311.5	12.4	0.009
NO_2	45.6	1.8	0.001
PM_{10}	139.9	5.6	0.004
CO	1596.7	63.5	0.044
VOC	168.7	6.7	0.005

GÜZELBAHÇE

Total emissions and fuel consumption of the districts of Güzelbahçe in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Atatürk	No use of Natural Gas	1205	13.1	1.6	5.9	67.1	7.1
Çamlı		687	7.5	0.9	3.4	38.3	4.0
Çelebi		857	9.3	1.1	4.2	47.7	5.0
Kahramandere		1074	11.7	1.4	5.3	59.8	6.3
Küçükkaya		71	0.8	0.1	0.3	4.0	0.4
Maltepe		1108	12.1	1.5	5.4	61.7	6.5
Mustafa K. P.		744	8.1	1.0	3.6	41.4	4.4
Payamlı		191	2.1	0.3	0.9	10.6	1.1
Siteler		1177	12.8	1.6	5.8	65.5	6.9
Yaka		314	3.4	0.4	1.5	17.5	1.8
Yalı		2366	25.8	3.1	11.6	131.8	13.9
Yelki		635	6.9	0.8	3.1	35.4	3.7
Total		**10429**	**113.6**	**13.9**	**51.0**	**580.8**	**61.1**

The amount of emissions in Güzelbahçe per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	113.6	1.8	0.011
NO_2	13.9	0.2	0.001
PM_{10}	51.0	0.8	0.005
CO	580.8	9.1	0.056
VOC	61.1	0.9	0.006

KARABAĞLAR

Total emissions and fuel consumption of the districts of Karabağlar in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Abdi İpekçi	-	1849	20.1	2.5	9.0	103.0	10.8
Adnansüvari	-	1639	17.8	2.2	8.0	91.3	9.6
Ali Fuat C.	-	2426	26.4	3.2	11.9	135.1	14.2
Ali Fuat E.	-	617	6.7	0.8	3.0	34.4	3.6
Araphasan	-	4622	50.3	6.1	22.6	257.4	27.1
Aşık Veysel	-	951	10.4	1.3	4.7	53.0	5.6
Aydın	-	2634	28.7	3.5	12.9	146.7	15.4
Bahar	292964	3216	35.0	4.8	15.7	179.4	18.9
Bahçelievler	379929	5146	56.0	7.5	25.2	287.0	30.3
Bahriye Üçok	-	895	9.7	1.2	4.4	49.8	5.2
Barış	-	2758	30.0	3.7	13.5	153.6	16.2
Basınsitesi	-	7057	76.9	9.4	34.5	393.0	41.4
Bozyaka	-	4390	47.8	5.8	21.5	244.5	25.7
Cennetçeşme	-	1019	11.1	1.4	5.0	56.7	6.0
Cennetoğlu	-	1672	18.2	2.2	8.2	93.1	9.8
Çalıkuşu	11726	3694	40.2	4.9	18.1	205.7	21.7
Devrim	-	2046	22.3	2.7	10.0	113.9	12.0
Doğanay	209368	3519	38.3	5.1	17.2	196.2	20.7
Esenlik	39822	2791	30.4	3.8	13.6	155.5	16.4
Esentepe	-	2775	30.2	3.7	13.6	154.5	16.3
Esenyalı	-	3703	40.3	4.9	18.1	206.2	21.7
Fahrettin Altay	-	3930	42.8	5.2	19.2	218.9	23.0
Gazi	-	1477	16.1	2.0	7.2	82.3	8.7
General A. G.	-	657	7.2	0.9	3.2	36.6	3.9
General K. Ö.	-	1232	13.4	1.6	6.0	68.6	7.2
Gülyaka	21550	3108	33.8	4.2	15.2	173.1	18.2
Günaltay	-	5492	59.8	7.3	26.9	305.8	32.2
İhsan Alyanak	-	2887	31.4	3.8	14.1	160.8	16.9
Karabağlar	-	2829	30.8	3.8	13.8	157.5	16.6
Kavacık	-	432	4.7	0.6	2.1	24.1	2.5
Kazımkarabekir	109504	3415	37.2	4.7	16.7	190.3	20.0
Kibar	-	1226	13.4	1.6	6.0	68.3	7.2
Limontepe	-	1515	16.5	2.0	7.4	84.4	8.9
Maliyeceler	-	1769	19.3	2.4	8.7	98.5	10.4
Metin Oktay	-	2572	28.0	3.4	12.6	143.2	15.1
Muammer Akar	-	3270	35.6	4.3	16.0	182.1	19.2
Osman A.	-	397	4.3	0.5	1.9	22.1	2.3
Özgür	-	1923	20.9	2.6	9.4	107.1	11.3
Peker	-	3296	35.9	4.4	16.1	183.6	19.3
Poligon	-	1757	19.1	2.3	8.6	97.8	10.3
Refetbele	777	2363	25.7	3.1	11.6	131.6	13.8
Reis	188804	3155	34.4	4.5	15.4	175.9	18.5
Salih Omurtak	-	2025	22.1	2.7	9.9	112.8	11.9
Sarıyer	-	3089	33.6	4.1	15.1	172.0	18.1
Selvili	-	2777	30.2	3.7	13.6	154.7	16.3
Sevgi	-	2289	24.9	3.0	11.2	127.5	13.4
Şehitler	-	1072	11.7	1.4	5.2	59.7	6.3

Total emissions and fuel consumption of the districts of Karabağlar in 2008-09 winter season (continued).

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Tahsin Yazıcı	-	2786	30.3	3.7	13.6	155.2	16.3
Tırazlı	-	107	1.2	0.1	0.5	6.0	0.6
Uğur Mumcu	-	2800	30.5	3.7	13.7	155.9	16.4
Umut	-	3094	33.7	4.1	15.1	172.3	18.1
Uzundere	-	4177	45.5	5.6	20.4	232.6	24.5
Üç Kuyular	-	4522	49.2	6.0	22.1	251.8	26.5
Vatan	5428	7975	86.8	10.6	39.0	444.1	46.7
Yunus Emre	-	6954	75.7	9.2	34.0	387.3	40.8
Yurtdoğlu	-	3374	36.7	4.5	16.5	187.9	19.8
Yüzbaşı Ş.	-	1745	19.0	2.3	8.5	97.2	10.2
Total	**1259872**	**156907**	**1708.7**	**211.0**	**767.3**	**8739.4**	**919.8**

The amount of emissions in Karabağlar per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	1708.7	18.6	0.011
NO_2	211.0	2.3	0.001
PM_{10}	767.3	8.3	0.005
CO	8739.4	95.0	0.055
VOC	919.8	9.9	0.006

KONAK

Total emissions and fuel consumption of the districts of Konak in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Akarcalı	-	1678	18.3	2.2	8.2	93.4	9.8
Akdeniz	-	238	2.6	0.3	1.2	13.3	1.4
Akınsimav	20265	2141	23.3	2.9	10.5	119.3	12.6
Akıncı	-	90	1.0	0.1	0.4	5.0	0.5
Ali Reis	-	835	9.1	1.1	4.1	46.5	4.9
Alsancak	-	3631	39.5	4.8	17.8	202.2	21.3
Altay	-	659	7.2	0.9	3.2	36.7	3.9
Altınordu	-	313	3.4	0.4	1.5	17.4	1.8
Altıntaş	64805	2683	29.2	3.7	13.1	149.5	15.7
Anadolu	-	933	10.2	1.2	4.6	52.0	5.5
Atamer	-	1230	13.4	1.6	6.0	68.5	7.2
Atilla	95859	4495	49.0	6.2	22.0	250.4	26.4
Aziziye	-	1561	17.0	2.1	7.6	86.9	9.1
Barbaros	41116	1761	19.2	2.4	8.6	98.1	10.3
Boğaziçi	-	3310	36.0	4.4	16.2	184.3	19.4
Bozkurt	-	1856	20.2	2.5	9.1	103.4	10.9
Cengiz T.	-	1173	12.8	1.6	5.7	65.3	6.9
Çahabey	-	312	3.4	0.4	1.5	17.4	1.8
Çankaya	-	5288	57.6	7.0	25.9	294.5	31.0
Çınarlı	-	63	0.7	0.1	0.3	3.5	0.4
Çınartepe	-	1772	19.3	2.4	8.7	98.7	10.4
Çimentepe	-	1184	12.9	1.6	5.8	65.9	6.9
Dayıemir	-	328	3.6	0.4	1.6	18.3	1.9
Dolaplı K.	-	394	4.3	0.5	1.9	21.9	2.3
Duatepe	-	955	10.4	1.3	4.7	53.2	5.6
Ege	-	695	7.6	0.9	3.4	38.7	4.1
Emir Sultan	-	769	8.4	1.0	3.8	42.8	4.5
Etiler	-	811	8.8	1.1	4.0	45.2	4.8
Faik Paşa	-	526	5.7	0.7	2.6	29.3	3.1
Fatih	-	352	3.8	0.5	1.7	19.6	2.1
Ferahlı	-	4101	44.7	5.5	20.1	228.4	24.0
Fevzi Paşa	-	17	0.2	0.0	0.1	0.9	0.1
Göztepe	-	7977	86.9	10.6	39.0	444.2	46.7
Güneş	-	16	0.2	0.0	0.1	0.9	0.1
Güneşli	181226	2306	25.1	3.4	11.3	128.6	13.6
Güney	-	2003	21.8	2.7	9.8	111.5	11.7
Güngör	3865	566	6.2	0.8	2.8	31.5	3.3
Güzelyalı	-	8167	88.9	10.9	39.9	454.8	47.9
Güzelyurt	-	1	0.0	0.0	0.0	0.1	0.0
Halkapınar	-	240	2.6	0.3	1.2	13.4	1.4
Hasan Ö.	-	1085	11.8	1.4	5.3	60.4	6.4
Hilal	-	865	9.4	1.2	4.2	48.2	5.1
Hurşidiye	-	19	0.2	0.0	0.1	1.1	0.1
Huzur	-	1153	12.6	1.5	5.6	64.2	6.8
İmariye	-	2367	25.8	3.1	11.6	131.8	13.9
İsmet K.	-	91	1.0	0.1	0.4	5.1	0.5
İsmet Paşa	-	2503	27.3	3.3	12.2	139.4	14.7
Kadifekale	-	2264	24.7	3.0	11.1	126.1	13.3

Total emissions and fuel consumption of the districts of Konak in 2008-09 winter season (continued).

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Kahraman	-	61	0.7	0.1	0.3	3.4	0.4
Kahramanlar	-	2251	24.5	3.0	11.0	125.4	13.2
Kemalreis	33301	1528	16.6	2.1	7.5	85.1	9.0
Kestelli	-	10	0.1	0.0	0.0	0.6	0.1
Kılıç Reis	-	3589	39.1	4.8	17.6	199.9	21.0
Kocakapı	-	1284	14.0	1.7	6.3	71.5	7.5
Kocatepe	-	734	8.0	1.0	3.6	40.9	4.3
Konak	-	22	0.2	0.0	0.1	1.2	0.1
Kosova	-	1200	13.1	1.6	5.9	66.8	7.0
Kubilay	-	1127	12.3	1.5	5.5	62.8	6.6
Kurtuluş	-	37	0.4	0.0	0.2	2.1	0.2
Küçükada	-	1496	16.3	2.0	7.3	83.3	8.8
Kültür	-	4863	53.0	6.5	23.8	270.8	28.5
Lale	-	1848	20.1	2.5	9.0	102.9	10.8
Levent	-	2215	24.1	2.9	10.8	123.4	13.0
Mecidiye	721	253	2.8	0.3	1.2	14.1	1.5
Mehmetakif	-	983	10.7	1.3	4.8	54.7	5.8
Mehmet A.A.	-	3225	35.1	4.3	15.8	179.6	18.9
Mehtap	-	1730	18.8	2.3	8.5	96.3	10.1
Mersinli	-	1093	11.9	1.5	5.3	60.9	6.4
Millet	-	2040	22.2	2.7	10.0	113.6	12.0
Mimarsinan	-	3215	35.0	4.3	15.7	179.0	18.8
Mirali	-	359	3.9	0.5	1.8	20.0	2.1
Mithatpaşa	21852	3812	41.5	5.1	18.6	212.3	22.3
Murat	-	2277	24.8	3.0	11.1	126.8	13.3
Muratreis	1067	5741	62.5	7.6	28.1	319.9	33.7
Namazgah	-	3	0.0	0.0	0.0	0.2	0.0
Namık K.l	-	317	3.5	0.4	1.6	17.7	1.9
Odun Kapı	-	125	1.4	0.2	0.6	7.0	0.7
Oğuzlar	-	92	1.0	0.1	0.4	5.1	0.5
Pazaryeri	-	469	5.1	0.6	2.3	26.1	2.7
Pirireis	5779	2143	23.3	2.9	10.5	119.3	12.6
Sakarya	-	392	4.3	0.5	1.9	21.8	2.3
Saygı	-	2069	22.5	2.8	10.1	115.2	12.1
Selçuk	-	1350	14.7	1.8	6.6	75.2	7.9
Sümer	-	83	0.9	0.1	0.4	4.6	0.5
Süvari	-	718	7.8	1.0	3.5	40.0	4.2
Şehit N. T.	-	98	1.1	0.1	0.5	5.5	0.6
Tan	-	54	0.6	0.1	0.3	3.0	0.3
Tınaztepe	-	872	9.5	1.2	4.3	48.6	5.1
Trakya	-	922	10.0	1.2	4.5	51.3	5.4
Turgutreis	13701	1640	17.9	2.2	8.0	91.3	9.6
Tuzcu	-	847	9.2	1.1	4.1	47.2	5.0
Türkyılmaz	-	162	1.8	0.2	0.8	9.0	0.9
Uğur	-	35	0.4	0.0	0.2	1.9	0.2
Ulubatlı	-	3475	37.8	4.6	17.0	193.5	20.4
Umurbey	-	306	3.3	0.4	1.5	17.0	1.8
Ülkü	-	629	6.8	0.8	3.1	35.0	3.7
Vezirağa	-	195	2.1	0.3	1.0	10.9	1.1
Yavuz Selim	-	839	9.1	1.1	4.1	46.7	4.9
Yeni	-	382	4.2	0.5	1.9	21.3	2.2

Total emissions and fuel consumption of the districts of Konak in 2008-09 winter season (continued).

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
Yenidoğan	-	1053	11.5	1.4	5.1	58.6	6.2
Yenigün	-	7	0.1	0.0	0.0	0.4	0.0
Yenişehir	-	1185	12.9	1.6	5.8	66.0	6.9
Yeşildere	-	1318	14.4	1.8	6.4	73.4	7.7
Yeşiltepe	-	555	6.0	0.7	2.7	30.9	3.3
Yıldız	-	89	1.0	0.1	0.4	5.0	0.5
Zafertepe	-	3596	39.2	4.8	17.6	200.3	21.1
Zeybek	-	952	10.4	1.3	4.7	53.0	5.6
Zeytinlik	-	3183	34.7	4.2	15.6	177.3	18.7
1. Kadriye	-	2619	28.5	3.5	12.8	145.9	15.3
19 Mayıs	-	1277	13.9	1.7	6.2	71.1	7.5
2. Kadriye	-	2578	28.1	3.4	12.6	143.6	15.1
26 Ağustos	-	1383	15.1	1.8	6.8	77.0	8.1
Total	**483557**	**162782**	**1772.7**	**217.4**	**796.0**	**9065.9**	**954.0**

The amount of emissions in Konak per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	1772.7	74.4	0.011
NO_2	217.4	9.1	0.001
PM_{10}	796.0	33.4	0.005
CO	9065.9	380.3	0.055
VOC	954.0	40.0	0.006

KARŞIYAKA

Total emissions and fuel consumption of the districts of Karşıyaka in 2008-09 winter season.

DISTRICT	**The Consumption of NG (m^3)**	**The Consumption of Coal (tons)**	**SO_2 (tons/year)**	**NO_2 (tons/year)**	**PM_{10} (tons/year)**	**CO (tons/year)**	**VOC (tons/year)**
Aksoy	982606	4564	49.7	7.9	22.3	255.2	27.0
Alaybey	236476	2971	32.4	4.4	14.5	165.7	17.5
Atakent	1801997	1745	19.0	5.7	8.6	99.0	10.7
Bahariye	-	5485	59.7	7.3	26.8	305.5	32.1
Bahçelievler.	237052	8216	89.5	11.4	40.2	457.8	48.2
Bahriye Ü.	354672	4841	52.7	7.1	23.7	270.0	28.5
Bostanlı	3675632	9931	108.2	20.0	48.6	556.8	59.2
Cumhuriyet	-	5379	58.6	7.2	26.3	299.6	31.5
Dedebaşı	82217	5001	54.5	6.8	24.5	278.6	29.3
Demirköprü	-	1758	19.1	2.3	8.6	97.9	10.3
Donanmacı	797648	4172	45.4	7.0	20.4	233.1	24.7
Fikrialtay	-	1935	21.1	2.6	9.5	107.8	11.3
Goncalar	126122	3188	34.7	4.5	15.6	177.7	18.7
İmbatlı	-	2190	23.8	2.9	10.7	122.0	12.8
İnönü	61921	1190	13.0	1.7	5.8	66.3	7.0
Mavişehir	4868016	451	5.0	9.6	2.3	30.0	4.0
Mustafa K.	1176499	0	0.0	2.2	0.0	1.2	0.3
Nergiz	176157	2990	32.6	4.3	14.6	166.7	17.6
Örnekköy	-	5553	60.5	7.4	27.2	309.2	32.5
Sancaklı	-	64	0.7	0.1	0.3	3.6	0.4
Şemikler	153302	6403	69.7	8.8	31.3	356.7	37.6
Tersane	52912	2998	32.6	4.1	14.7	167.0	17.6
Tuna	157881	2805	30.5	4.0	13.7	156.4	16.5
Yalı	2104475	4459	48.6	9.8	21.8	250.4	26.7
Yamanlar	-	5050	55.0	6.7	24.7	281.2	29.6
Zübeyde H.	-	4116	44.8	5.5	20.1	229.2	24.1
Total	**17045585**	**97455**	**1061.6**	**161.1**	**476.9**	**5444.5**	**575.7**

The amount of emissions in Karşıyaka per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km^2**	**tons/year/house**
SO_2	1061.6	24.6	0.009
NO_2	161.1	3.7	0.001
PM_{10}	476.9	11.0	0.004
CO	5444.5	125.9	0.044
VOC	575.7	13.3	0.005

NARLIDERE

Total emissions and fuel consumption of the districts of Narlıdere in 2008-09 winter season.

DISTRICT	The Consumption of NG (m^3)	The Consumption of Coal (tons)	SO_2 (tons/year)	NO_2 (tons/year)	PM_{10} (tons/year)	CO (tons/year)	VOC (tons/year)
2. İnönü	No use of Natural Gas	2172	23.7	2.9	10.6	121.0	12.7
Altıevler		680	7.4	0.9	3.3	37.9	4.0
Atatürk		1597	17.4	2.1	7.8	88.9	9.4
Çamtepe		3018	32.9	4.0	14.8	168.1	17.7
Çatalkaya		2520	27.4	3.4	12.3	140.3	14.8
Huzur		1894	20.6	2.5	9.3	105.5	11.1
Ilıca*		2430	26.5	3.2	11.9	135.3	14.2
Limanreis		1166	12.7	1.6	5.7	64.9	6.8
Narlı		2674	29.1	3.6	13.1	148.9	15.7
Sahilevleri*			0.0	0.0	0.0	0.0	0.0
Yenikale*		0	0.0	0.0	0.0	0.0	0.0
Total		**18151**	**197.7**	**24.1**	**88.8**	**1010.8**	**106.4**

* Geothermal energy is used for domestic heating in these quarters.

The amount of emissions in Narlıdere per area and household in 2008-09 winter season.

	EMISSIONS		
	tons/year	**tons/year/km²**	**tons/year/house**
SO_2	138.8	9.1	0.005
NO_2	17.0	1.1	0.001
PM_{10}	62.3	4.1	0.002
CO	709.9	46.3	0.023
VOC	74.7	4.8	0.002