DEVELOPMENT OF AN ENVIRONMENTAL POLLUTION INDEX FOR THE MIDDLE SECTION OF SEYHAN BASIN

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

MEHMET GÖLGE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
ENVIRONMENTAL ENGINEERING

MAY 2010

DEVELOPMENT OF AN ENVIRONMENTAL POLLUTION INDEX FOR THE MIDDLE SECTION OF SEYHAN BASIN

Submitted by **MEHMET GÖLGE** in partial fulfillment of the requirements for the degree of **Master of Science in Environmental Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen ____________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Göksel N. Demirer ____________________
Head of Department, **Environmental Engineering**

Assoc. Prof. Dr. Ayşegül Aksoy ____________________
Supervisor, **Environmental Engineering Dept., METU**

Examining Committee Members:

Prof. Dr. Aysel Atımtay ____________________
Environmental Engineering Dept., METU

Assoc. Prof. Dr. Ayşegül Aksoy ____________________
Environmental Engineering Dept., METU

Dr. Tuba Hande Ergüder ____________________
Environmental Engineering Dept., METU

Dr. Barış Kaymak ____________________
Environmental Engineering Dept., METU

Assist. Prof. Dr. Harun Aydın ____________________
Environmental Engineering Dept., 100. Yıl University

Date: 03/05/2010

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Mehmet GÖLGE

Signature :

ABSTRACT

DEVELOPMENT OF AN ENVIRONMENTAL POLLUTION INDEX FOR THE MIDDLE SECTION OF SEYHAN BASIN

Gölge, Mehmet
M.S., Department of Environmental Engineering
Supervisor: Assoc. Prof. Dr. Ayşegül Aksoy

May 2010, 167 pages

In this study, it is aimed to develop a database on Seyhan River Basin; and an environmental pollution index for the middle section of Seyhan Basin by combining different pollution indices such as water, and air. Water and air pollution indices are developed for the selected quality monitoring stations and the selected years. Water pollution index is calculated by using the method suggested by National Sanitation Foundation of United States, and air pollution index is developed according to the modified Environmental Protection Agency's air pollution index. As aggregation method, weighted arithmetic mean function is used for development of indices. After development of separate water and air pollution indices, environmental pollution index is developed for the year 2008 by two aggregation methods, one based on linguistic interpretation and the other again on weighted arithmetic mean function. The water pollution index for the middle section of the basin is determined as "good", and air pollution index as "low pollution". According to calculated water and air pollution indices, environmental pollution index is calculated with two methods and obtained the index equal to 4, which is classified as "good". Although, both of the methods give same result in development of environmental pollution index, the second method based on weighted arithmetic mean function concluded to be more user friendly.

Keywords: environmental pollution index, water pollution index, air pollution index, Seyhan Basin

ÖZ

SEYHAN HAVZASI ORTA BÖLÜMÜ İÇİN ÇEVRESEL KİRLİLİK İNDEKSİ GELİŞTİRİLMESİ

Gölge, Mehmet
Yüksek Lisans, Çevre Mühendisliği Bölümü
Tez Yöneticisi: Doç. Dr. Ayşegül Aksoy

Mayıs 2010, 167 sayfa

Bu çalışmada, Seyhan Nehir Havzası için bir veritabanı oluşturulması ve su ve hava gibi farklı kirlilik indekslerini kullanarak Seyhan Havzası orta bölümü için bir çevresel kirlilik indeksi geliştirilmesi amaçlanmıştır. Su ve hava kirliliği indeksleri seçilen kalite gözlem istasyonları ve yıllar için geliştirilmiştir. Su kirliliği indeksi Amerika Birleşik Devletleri Ulusal Sağlık Teşkilatınca önerilen metot ile, hava kirliliği ise Amerika Birleşik Devletleri Çevre Koruma Ajansı tarafından önerilen hava kirliliği indeksinin modifiye edilmiş haline göre hesaplanmıştır. İndekslerin geliştirilmesinde agregasyon metodu olarak ağırlıklı aritmetik ortalama fonksiyonu kullanılmıştır. Ayrı ayrı su ve hava kirlilik indekslerinin geliştirilmesinin ardından sözel yorumlama ve yine ağırlıklı aritmetik ortalamaya dayanan iki farklı agregasyon yöntemi ile 2008 yılı için çevresel kirlilik indeksi geliştirilmiştir. Seyhan Havzası orta bölümü için su kirlilik indeksi "iyi", hava kirlilik indeksi ise "düşük kirlilik" olarak tespit edilmiştir. Hesaplanan su ve hava kirliliği indekslerine göre çevresel kirlilik indeksi de "iyi" sınıfına girecek şekilde 4 olarak elde edilmiştir. Çevresel kirlilik indeksi hesaplanmasında her iki yöntem de aynı sonucu vermesine rağmen, ağırlıklı aritmetik ortalamaya dayanan ikinci yöntem daha kullanışlı olarak değerlendirilmiştir.

Anahtar Kelimeler: çevresel kirlilik indeksi, su kirliliği indeksi, hava kirliliği indeksi, Seyhan Havzası

To my family

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my supervisor Assoc. Prof. Dr. Aysegül Aksoy for her guidance, advice, criticism, encouragements and insight throughout the research.

I would like to also thank my committee members Prof. Dr. Aysel Atımtay, Dr. Tuba Hande Ergüder, Dr. Barış Kaymak, and Assist. Prof. Dr. Harun Aydın for their time, effort and enlightening suggestions towards improvement of the quality of this thesis. I am very grateful for their input.

I would also like to thank Dr. Harun Aydın (Hydrogeological Engineer, PhD), Dr. B. Teoman Meriç (Hydrogeological Engineer, PhD), Mr. Özkan Kılıç (Computer Engineer, MSc), Ms. Firdes Yenilmez (Environmental Engineer, MSc), Ms. Ayşegül Demir (Environmental Engineer, MSc), Ms. Kamile Kalaycı (Agricultural Engineer, MSc), Mr. A. Ozan Çekiç (Forest Engineer), and Mr. Yusuf Ceran (Agricultural Engineer) for their suggestions and comments and support.

Finally, I would like to thank to my family for their unconditional love, patience and eternal support. Without them, this thesis would never have finished.

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LIST OF ABBREVIATIONS

AQI	Air Quality Index
API	Air Pollution Index
AWPI	Air and Water Pollution Index
ÇYGM	General Directorate of Environmental Management
BOD	Biochemical Oxygen Demand
BOD_5	5-day Biochemical Oxygen Demand
CEI	Composite Environmental Index
CLCC	CORINE Land Cover Classification
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CORINE	Coordination of Information on the Environment
DEM	Digital Elevation Model
DKMP	General Directorate of Nature Conservation and National Parks
DMI	Turkish State Meteorological Service
DO	Dissolved Oxygen
DSI	General Directorate of State Hydraulics Works
EC	European Commission
EEA	European Environment Agency
EEC	European Economic Community
EIE	General Directorate of Electrical Power Resources Survey and Development Administration
EQI	Environmental Quality Index
EPA	Environmental Protection Agency of United States
EPI	Environmental Pollution Index
EU	European Union

IDW	Inverse Distance Weighted
LPI	Leachate Pollution Index
MoEF	Ministry of Environment and Forestry
NAAQS	National Ambient Air Quality Standards
NSF	National Sanitation Foundation of United States
NO_2	Nitrogen Dioxide
NO_3	Nitrates
O_3	Ozone
OG	Official Gazette of Republic of Turkey
PO_4	Total Phosphates
POC	Permanganate Oxidizable Compounds
PSI	Pollution Standards Index
PM	Particulate Matter
SKKY	Turkish Regulation on Water Pollution Control
SO_2	Sulfur Dioxide
T	Temperature
TDS	Total Dissolved Solids
T-N	Total Nitrogen
TUIK	Turkish Statistical Institute
TOC	Total Organic Carbon
T-P	Total Phosphates
TS	Total Solids
TSS	Total Suspended Solids
UTM	Universal Tranverse Mercator
UWQI	Universal Water Quality Index
VOC	Volatile Organic Compound
WFD	The Water Framework Directive
WHO	World Health Organization
WQE	Water Quality Evaluation
WQI	Water Quality Index
WPI	Water Pollution Index

CHAPTER 1

INTRODUCTION

European Environment Agency (EEA) defined "environmental quality" as "*Properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms. Environmental quality is a general term which can refer to: varied characteristics such as air and water purity or pollution, noise, access to open space, and the visual effects of buildings, and the potential effects which such characteristics may have on physical and mental health (caused by human activities)*" (EEA, 2010).

When the environmental quality reports are produced, they are especially written for the experts, and usually they do not give an idea for the people who are not expert. Also, "to monitor quality and to make qualitative and quantitative assessment based on real data has become a challenge for environmental engineers" (Lermontov et al., 2009). In this context, methods to integrate several variables related with environmental quality in an index are needed.

EEA also defined "environmental indicator" as "*A parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action*" (EEA, 2010). The purpose of environmental pollution index is to simplify and clarify environmental quality assessment "by transforming large quantities of data into a single number, which represents the environmental quality level (Sanchez et al., 2007)". This single number makes information more easily and rapidly understood than a long list of numerical values for a large variety of parameters (Debels et al., 2005). These indices are developed “for a variety of purposes ranging from enforcement of environmental standards, to analysis of trends of environmental degradation or improvement, to scientific research” (Pykh et al., 2000)

Environmental pollution indices (EPIs) are used for several purposes such as (Pykh et al., 2000):

- Reducing a large quantity of data to a simple form which gives insights to the researcher conducting a study related to some environmental issues,
- Assisting decision makers for allocation of funds and setting priorities in environmental decisions,
- Determination of application of legislative standards and existing criteria,
- Comparison of environmental conditions of different areas,
- Determination of changes in environmental quality of different points in time,
- Inform public about environmental situation.

This determination of pollution index study will be carried for Seyhan River Basin, which is located in the Eastern Mediterranean Region of Turkey, between latitudes 36° 30’ and 39° 15’ North, and longitudes 34° 45’ and 37° 00’ East. The basin covers an area of 22.139 km^2. Most part of the basin is located in the province borders of Adana and Kayseri. Very minor parts of Sivas, Kahramanmaraş and Niğde provinces are also in the area of the basin.

Seyhan River is formed of two river systems: Zamantı River, which originates in the eastern section of Central Anatolia (Uzunyayla region), and further to the east Göksu River, which originates in Eastern Anatolia. The main tributaries of Seyhan River include Eğlence, Körkün, Üçürge and Çakıt streams.

The purpose of this study is to develop a database on Seyhan River Basin; and develop an environmental pollution index to assess the environmental quality in the middle section of Seyhan Basin by using the data in the database. The objective of the index development is to assess vulnerability focusing on water and air quality. For this purpose, a methodology consisting of selection of appropriate water and air quality parameters, development or selection of normalization functions, assignment of weight factors to parameters and development of an aggregation function is followed to achieve a final index score.

CHAPTER 2

BACKGROUND

2.1. POLLUTION INDICES

The purpose of the all indices, water, air and soil, is not to describe separately a pollutant's concentration or the changes in a certain parameter. Instead, indices aim to set environmental priorities for areas, compare regions in terms of the environmental conditions, inform the public about the conditions and scrutinize the changes in these conditions. The indices are "considered more trustful than isolated variables because they integrate several variables in a single number by combining different units of measurement via the help of experiments, observations and cautious studies. A problem with the indexing process is the possibility that some parameters have a disproportional influence on the final result, producing a biased index" (Lermontov et al, 2009). In other words, combining "which variables and how" are the main problem of various indexing methodologies resulting in different measures. There are many researches to overcome this problem in evaluation of water, air and soil pollution indices. In the following section, firstly the Water Quality Index (WQI) and Air Quality Index (AQI) methodologies in the literature are reviewed. Then combining the different index evaluation methodologies is discussed.

To begin with, the "WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which summarize different quality parameters. The WQI is an index of water quality for a particular use. Mathematically, the index is an arithmetic weighting of normalized water quality measurements. The normalizations, as well as the weightings, are different for different water usages (Pesce and Wunderlin, 2000; Simões *et al*., 2008). The WQI concept is based on the comparison of the water quality parameter with respective regulatory standards" (Khan et al., 2003; Boyacıoğlu, 2007). The development process of a water quality index can be generalized in four steps (Boyacıoğlu, 2007):

1. Selecting the set of water quality variables of concern – *parameter selection*
2. Transformation of the different units and dimensions of water quality variables to a common scale – *sub-index development*
3. Weighting of the water quality variables based on their relative importance to overall water quality – *weight assignment*
4. Formulation of overall water quality index – *aggregation of sub-indices to produce an overall index* (Boyacıoğlu, 2007).

"To monitor water quality and to make qualitative and quantitative decisions based on real data has become a challenge for environmental engineers from data collection, storage and processing up to analyze and interpretation of the results. Uncertainties and disagreements accumulate along this chain" (Lermontov *et al*, 2009) and result in different approaches among researchers.

Since WQI is "directly affected by a large number of environmental variables, a clear definition of the goals to be attained by the use of such an index is needed. The formulation of a WQI may be simplified if one considers only the variables which are deemed critical for a certain water body" (Lermontov *et al*, 2009). For example, in a groundbreaking work, Horton (1965 in Lermontov *et al*, 2009) developed general water quality indices, selecting and weighting several parameters. This methodology was then improved by the National Sanitation Foundation (NSF) of United States (Ott, 1978). "The use of WQI is a simple practice, which allows adequate classification of water quality. The determination of a conventional WQI requires a normalization step where each parameter is transformed into a 0–100 scale, where 100 represents the perfect water quality conditions. The next step is to apply a weighting factor in accordance with the importance of the parameter as an indicator of water quality" (Gilijanovi, 1999; Pesce and Wunderlin, 2000; Jonnalagadda and Mhere, 2001; Sanchez *et al*., 2007).

Indices have been suggested "as a means of aggregating dimensions of the water quality concept to make inferences about trends in watershed environmental quality. An index aggregates information about water-quality parameters at different times and in different places and translates this information into a single statistic that is representative of the time period and spatial unit under consideration. There are no hard and fast rules for constructing an index. In each case, rules are derived from a specific understanding of how the index will be interpreted and how it will be used. Therefore, a water-quality index should be specific to a water use or a set of goals" (Schultz, 2001).

In order to evaluate the water quality of aquatic systems many countries have introduced a plan to monitor and assess the pollution effects (Pesce and Wunderlin, 2002; Simões *et al.*, 2008). For this, "chemical, physical and biological constituents are quantified in all rivers of the world. The problem is the quantity of analysis required and cost to accomplish them. In order to resolve this problem regulatory agencies" such as governmental institutions and ministries have been created and have used a general index as a management tool. "One of the first of these tools is the WQI developed by the NSF which is based on analysis of nine parameters: fecal coliform, pH, biochemical oxygen demand (BOD), total nitrogen, total phosphorus, temperature, turbidity, total residue and dissolved oxygen. Its output ranges from 0 to 100, where 100 represents perfect water quality conditions while zero indicates water that is not suitable for the intended use without further treatment" (Shoji et al., 1966; Dunnette, 1979; Couillard and Lefebvre, 1985; Miller et al., 1986; Tyson and House, 1989; Chang et al., 2001; Bordalo et al., 2001, 2006; Simões et al., 2008).

WQI “can be simplified considering only critical environmental variables that affect the quality of a certain aquatic body as a function of the soil use and occupation.” Simões *et al.* (2008) chosed the parameters total phosphorous, turbidity, and dissolved oxygen and used to infer the effects of fish farming activities. The WQI used by Simões *et al.* (2008) were calculated in three different ways and based on parameters. The first one produced “a WQI_{NFS} based on the parameters proposed by Brown and Forsythe (1974) including: biochemical oxygen demand, dissolved oxygen, total fecal coliform, pH, temperature, total nitrate, total phosphorus, total solids and turbidity”. This WQI is calculated using the following equation:

$$WQI = \sum_{i=1}^{n} q_i w_i \qquad (2.1)$$

$$\sum_{i=1}^{n} w_i = 1 \qquad (2.2)$$

where WQI is a number between 0 and 100 to indicate the water quality index; q_i is water quality score of parameter, a number between 0 and 100, obtained from the respective ‘‘curve average of quality’’ variation, as a function of concentration or measurement; *n* the number of parameter used to calculated WQI and, w_i the weighting factor of parameter *i*, a number between 0 and 1, attributed as a function of its importance for the global quality as described in Equation 2.2 and, *n* is the number of parameter (Simões *et al.*, 2008).

A second index was calculated using the “Minimum Operator Concept”, described in Equation 2.3, and proposed by Smith (1990). This author shows that water quality for a specific use is managed by the parameters that indicate the worst quality:

$$WQI_{moc} = Min(I_1, I_2, ..., I_n) \qquad (2.3)$$

where I is a specific physical chemistry parameter that is minimized in the calculation for this index. Equation 2.3 "establishes that the numerical value for WQI_{moc} is the lower normalized value for the all monitored variables. This kind of index removes the classic eclipse effect present in most index calculations" (Landwehr and Deininger, 1976; Simões *et al.*, 2008).

A third way to calculate an index was proposed by Pesce and Wunderlin (2000) "employing a computer program (Basic Language) especially developed for this purpose (Simões *et al.*, 2008). A water quality index with only three parameters, named minimal index (WQI_{min})" was calculated using the following equation:

$$WQI_{\min} = \frac{CDO + CTurb + CTotP}{3} \qquad (2.4)$$

where CDO is the value due to dissolved oxygen after normalization; CTurb the value due to turbidity after normalization; and CTotP is the value due to total phosphorus after normalization (Simões *et al.*, 2008).

Chang *et al.* (2001) presented a comparative study using three fuzzy synthetic evaluation techniques, which are "simple fuzzy classification, fuzzy similarity method, and fuzzy information intensity, to assess water quality conditions in comparison to the outputs generated by conventional procedures such as the WQI. Based on a set of data collected at seven sampling stations, a case study for the Tseng-Wen River system in Taiwan was used to demonstrate their application potential. The findings clearly indicate that the techniques may successfully harmonize inherent discrepancies and interpret complex conditions". A further, newly developed fuzzy synthetic evaluation approach described.

Stigter *et al.* (2006) showed the "application of a WQI as a monitoring tool for groundwater pollution from agricultural practices. Generally the main concern of pollution policies with respect to agriculture is the reduction of the input of nitrogen (N) to the environment. However, N is not the only element associated to agricultural pollution and by combining potentially affected ions (e.g. SO_4^{2-}, PO_4^{3-}, Cl^-, Ca^{2+}) into an index, a more comprehensive picture of the pollution state is provided" (Stigter *et al.*, 2006).

The methodology developed for the construction of the groundwater quality index "involves three steps: selection, standardization and aggregation of the parameters to be included. In the more common methods, standardization is often performed by creating empirical rating curves for each parameter, establishing a relationship between expected values and dimensionless sub-index values. The resulting values are then aggregated using some type of sum or mean (e.g. arithmetic, harmonic, geometric), frequently including individual weighing factors" (Stigter *et al.*, 2006).

Boyacıoğlu (2007) developed a new index called the Universal Water Quality Index (UWQI) to provide a simpler method for describing the quality of the surface water used for drinking water supply. The UWQI was developed on the basis of the water quality standards, which are "The quality required of surface water intended for the abstraction of drinking water in the Member States 75/440/EEC" set by the Council of the European Communities; "The classification of inland waters according to quality - Turkish Regulation on Water Pollution Control – SKKY"; and other reported scientific information. "UWQI parameters (water quality determinants) were selected among these 45 parameters. Based on expert opinions and international experiences, 12 water quality parameters including cadmium, cyanide, mercury, selenium, arsenic, fluoride, nitrate, dissolved oxygen, BOD, phosphorus, pH and total coliform were considered as the significant indicator parameters of UWQI to assess the quality of surface water sources" (Boyacıoğlu, 2007).

For UWQI calculation, firstly sub-indices are developed. Sub-indices are value functions (rating curves) to transform the different units and dimensions of water quality variables to a common scale. It is agreed to assign fixed sub-index values for reference concentration values to formulate equations. Then overall index has calculated (aggregation of sub-indices). Aggregation of sub-indices was performed using the weighted sum method. The assignment of weights to water quality variables was another task. The temporary weights ranged from 1 to 4 on a basic scale of importance. On this scale 1, 2, 3 and 4 denote respectively little, average, great and very great importance. Each weight was then divided by the sum of all weights to arrive at the final weight factor (Boyacıoğlu, 2007).

Boyacıoğlu (2007) represented the aggregation function as:

$$UWQI = \sum_{i=1}^{n} w_i I_i \tag{2.5}$$

Where W_i = weight for i^{th} parameter, and I_i = sub-index for i^{th} parameter.

The index value between 0 to less than 25 represents poor quality, 25 to less than 50 marginal quality, 50 to 75 fair quality, 75 to less than 95 good quality and above excellent quality (Boyacıoğlu, 2007).

Conesa Fernandes-Vitora (1997 in Lermontov *et al*, 2009) "modified the traditional method and created another index, called subjective water quality index (WQI_{sub}), which includes a subjective constant, *k*. This constant may assume values between 0.25 and 1.00 at intervals of 0.25, with 0.25 representing water apparently very polluted (strong smells and colors) and 1.00 water apparently very pure. The parameters used to calculate this index must be previously normalized using curves given by Conesa" (1995 in Lermontov et al, 2009). The objective water quality index (WQI_{obj}) results from the elimination of the subjective constant *k*.

$$WQI_{sub} = k \frac{\sum_i C_i \times P_i}{\sum_i P_i} \tag{2.6}$$

where k is the subjective constant; C_i the value of the i^{th} normalized parameter (Conesa, 1995 in Lermontov *et al*, 2009); and P_i the relative weight of the i^{th} parameter.

Water quality modeling involves the prediction of water pollution using mathematical simulation techniques. It can also be used to predict water quality in terms of the real observed data at a high frequency and over a long period of time. Thus far, a number of water quality models have been widely applied to assess water quality. However, there is a considerable need for a decision-making process to translate the modeling result into an understandable form and thereby help users to make relevant judgments and decisions (Song and Kim, 2009).

Song and Kim (2009) developed a new water quality index, namely the QUAL2E water quality index (QWQLI), to provide a simple description of the water quality modeling result from QUAL2E. BOD, Total nitrogen (T-N), and Total phosphates (T-P) are taken as the major indicative parameters and developed QWOLI on the water quality standards of Korea (Song and Kim, 2009) which consist of five classes. Then, the weights of BOD, T-N, and T-P of QWQLI were assigned and further normalized by the following Equation 2.7 and Equation 2.8:

$$W'_i = \frac{r_{Lowest}}{r_i} \tag{2.7}$$

$$Wi = \frac{w'_i}{\sum_{i=1}^{3} w'_i} \tag{2.8}$$

where r_{Lowest} is the lowest significant rating of BOD, T-N, and T-P. For each variable, r_i, w'_i, and w_i are, respectively, the significant rating value, temporary weight, and final (normalized) weight of that variable (Song and Kim, 2009). Finally, the aggregation function of QWOLI, as given by Equation 2.9, is based on the linear sum aggregation function.

$$QWQLI = \sum_{i=1}^{3} w_i I_i = w_{BOD} I_{BOD} + w_{TN} I_{TN} + w_{TP} I_{TP} \quad (2.9)$$

where w_{BOD}, w_{TN}, and w_{TP} are the weight values of BOD, T-N, and T-P, and I_{BOD}, I_{TN}, and I_{TP} are the sub-indices of BOD, T-N, and T-P, respectively (Song and Kim, 2009).

The objective of the WQI is "to inform about river quality for regulatory agencies of a specific watershed. This way the WQI contributes to the construction of a support system to take relevant decisions about a watershed. One of the bigger problems with to WQI elaboration is synthesize in a single number the complex reality where a lot of environmental variables have influence and then to classify water quality as excellent, good, regular, bad and poor. WQI can be simplified considering only critical environmental variables that affect the quality of a certain aquatic body as a function of the soil use and occupation" (Simões *et al*., 2008).

Sanchez *et al*. (2007) studied use of WQI and dissolved oxygen deficit (D) as indicators of the environmental quality watersheds as well. As a particular case the main surface watersheds located in Las Rozas, Madrid (Spain) were "monitored for a period of 2 years, from September 2001 to September 2003. For the determination of the WQI, European Standards for clean water were used as reference in each case. Finally, the exploration of the influence of the climate condition on the water quality was other objective of the study". Sanchez *et al*. (2007) carried out laboratory analyses for the determination of total suspended solids (TSS), ammonia, nitrite, nitrate, total phosphorus, chemical oxygen demand (COD) and 5-day biochemical oxygen demand (BOD_5). For the determination of the WQI of the different watersheds experiments in the study, Equation 2.14 was used (Pesce and Wunderlin, 2000 in Sanchez *et al*., 2007):

$$WQI = k \frac{\sum_i C_i \times P_i}{\sum_i P_i} \quad (2.10)$$

where k is a subjective constant with a maximum value of 1 for apparently good quality water and 0.25 for apparently highly polluted water, C_i is the normalized value of the parameter and P_i is the relative weight assigned to each parameter.
In relation to the parameter P_i, the maximum value of 4 was assigned to parameters of relevant importance for aquatic life as for example DO and TSS, while the minimum value (unity) was assigned to parameters with minor relevance such as for example temperature and pH. Calculation of WQI was based on European Standards (Sanchez *et al*., 2007). “When the values of WQI are in the range of 0–25, the water must be classified as ‘‘very bad’’; for a WQI value in the range of 25–50 the water is classified as ‘‘bad’’; for WQI values in the range of 51–70 the water classification is ‘‘medium’’; finally, when the WQI values are within the range of 71–90 water is classified as “good” and for 91–100 as ‘‘excellent’’ (Jonnalagadda and Mhere, 2001)”.

Pesce and Wunderlin (2000) reported a three-year monitoring of Suquia River water in Cordoba City of Argentina and nearby locations. They also assessed the impact of urban activities (represented by sewage discharges, run-off and non-point pollution), and then evaluated by using three different WOIs. Two WQIs (subjective and objective–WQI_{sub} and WQI_{obj}) take into consideration 20 parameters. The other WQI (minimal–WQI_{min}) was developed considering only three parameters: turbidity, dissolved oxygen and either conductivity or dissolved solids. Measured parameters include: alkalinity, ammonia, arsenic, BOD_5, calcium, chloride, COD, dissolved oxygen (DO), oil and grease (O and G), fecal coliforms, hardness, iron, magnesium, nitrates, nitrites, permanganate oxidizable compounds (POC), pH, phenolic compounds, orthophosphate phosphorus, solids: dissolved, dissolved volatile, suspended, suspended volatile and total, sulfates, sulfides, surfactants, anionic as methylene blue active substances, temperature, total coliforms, and turbidity. Organochlorine pesticides were also monitored during the entire period studied.

The subjective water quality index, WQI_{sub}, was calculated on the basis of the WQI proposed by Rodriguez de Bascaron (Conesa Fdez-Vitora V., 1995 in Pesce and Wunderlin, 2000) by using Equation 2.1. Only the parameters ammonia, BOD_5, Ca, Ch, COD, DO, hardness, magnesium, nitrates, nitrites, O and G, pH, orthophosphate phosphorus, dissolved and total solids, surfactants, temperature, total coliform and turbidity were considered for WQI_{sub} calculation (Pesce and Wunderlin, 2000).

Pesce and Wunderlin, (2000) calculated the objective water quality index (WQI_{obj}) was calculated using Equation 2.1 but with k =1 in all the cases to account only for variations due to measured parameters. Finally, a water quality index with only three parameters, named minimal index (WQI_{min}) was calculated using:

$$WQI_{\min} = \frac{C_{DO} + C_{cond} + C_{turb}}{3} \tag{2.11}$$

where C_{DO} is the value due to dissolved oxygen after normalization; C_{cond} the value due to either conductivity or dissolved solids (TDS) after normalization; and C_{turb} the value due to turbidity after normalization (Pesce and Wunderlin, 2000).

The WQI is a “mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts (Giljanovi, 1999).It includes the following nine parameters: BOD, DO, fecal coliform bacteria, pH, temperature, total nitrate, total phosphorus, total solids and turbidity”. Water quality was evaluated by an index as in Equation 2.12 (Giljanovi, 1999):

$$WQI = \frac{WQE}{WQE_{MAC}} \tag{2.12}$$

where water quality evaluation (WQE) is given in Equation 2.13.

$$WQE = \sum_{i=1}^{n} q_i w_i \tag{2.13}$$

where

$$\sum_{i=1}^{n} q_i w_i = weighedsum \tag{2.14}$$

where q_i=water quality score of parameter i; w_i=wighing factor of parameter I, and n=number of parameters.

Nine water quality parameters are used to determine the WQI, that are "temperature, mineralization, corrosion coefficient, K=(SO_4+Cl)/HCO_3, DO, BOD, total nitrogen, protein nitrogen, total phosphorus, total coliform (MPN coli/100 ml). After determining the nine parameters the results were recorded and transferred to a WQI in which the range of possible results of the parameters and their score values are shown. By summing up all parameters the water quality evaluation was obtained" (Giljanovi, 1999).

Another WQI is evaluated by using the leachate pollution from closed and active landfills because it affects human health and the environment to a great extent. The leachate produced from a landfill may enter the underlying groundwater or the adjoining surface water bodies and can seriously degrade the water quality Groundwater, once contaminated, is difficult if not impossible to recover (Kumar and Alappat, 2004).

For example, Kumar and Alappat (2004) conducted a survey using multiple questionnaires to develop a Leachate Pollution Index (LPI). The index is a mathematical method of calculating a single value from multiple chemical and biological test results of the landfill leachate. The single value LPI is like a grade that expresses the overall leachate contamination potential of a landfill, based on several leachate pollution parameters at a given time. It is an increasing scale index, wherein a higher index value indicates a poorer environmental condition. The 18 leachate pollution parameters selected for inclusion in the LPI were chromium, lead, COD) mercury, BOD_5) arsenic, cyanide, phenolic compounds, zinc, pH, total Kjeldahl nitrogen, nickel, total Coliform bacteria, ammonical nitrogen, TDS, copper, chlorides, and total iron.

In the field of environmental indices, aggregation methods are crucial as they affect the quality of result in many ways. Aggregation has been defined as "the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual component" (UNDESA, 2000). To select the most appropriate aggregation function for an environmental index, the various possible aggregation functions are applied. Those aggregation functions are given in Table 2.1 (Kumar and Alappat, 2004; Singh et al., 2008):

Table 2.1. Aggregation functions used for water quality and pollution indices

Aggregation Function	**Function Expression**
Unweighted arithmetic mean function (Unweighted additive form)	$WPI = \frac{1}{n}\sum_{i=1}^{n} q_i$
Weighted arithmetic mean function (Weighted linear sum aggregation function)	$WPI = \sum_{i=1}^{n} w_i q_i$
Root sum power function (Root sum power additive form)	$WPI = \left(\sum_{i=1}^{n} q_i^{\ r}\right)^{1/r}$
Weighted root sum power function (Weighted root sum power additive form)	$WPI = \left(\sum_{i=1}^{n} w_i q_i^{\ r}\right)^{1/r}$
Root mean square function (Root mean square additive form)	$WPI = \left(\frac{1}{n}\sum_{i=1}^{n} q_i^{\ 2}\right)^{1/2}$

Table 2.1. Aggregation functions used for water quality and pollution indices (continued)

Aggregation Function	**Function Expression**
Weighted root sum square function (weighted root sum square aggregation function)	$WPI = \frac{\left(\frac{1}{n}\sum_{i=1}^{n} w_i q_i^{\,2}\right)^{1/2}}{\sum_{i=1}^{n} w_i}$
Maximum operator function	$WPI = \max[q_1, q_2, ..., q_n]$
Minimum operator function	$WPI = \min[q_1, q_2, ..., q_n]$
Unweighted ambiguity and eclipsity free function	$WPI = \left(\sum_{i=1}^{n} q_i^r\right)^{1/r}$
Weighted ambiguity and eclipsity free function	$WPI = \left(\sum_{i=1}^{n} w_i q_i^r\right)^{1/r}$
Weighted average concentration function	$WPI = k\frac{\sum_{i=1}^{n} q_i C_i}{\sum_{i=1}^{n} C_i}$
Subindex powered weight function	$WPI = \sum_{i=1}^{n} q_i^{w_i}$
Unweighted multiplicative function	$WPI = \left(\prod_{i=1}^{n} q_i\right)^{1/n}$
Weighted multiplicative function (Weighted geometric mean function)	$WPI = \prod_{i=1}^{n} q_i^{w_i}$
Square root unweighted harmonic mean square function	$WPI = \sqrt{\frac{n}{\sum_{i=1}^{n}\frac{1}{q_i^2}}}$
where *WPI* = water pollution index *w* = weight of the i^{th} pollutant *q* = sub-index value for the i^{th} pollutant *C* = concentration of the i^{th} pollutant *r* = root (a positive real number greater than 1) *k* = a constant	

Another “mathematical instrument to transform large environmental quantities into a simple number is air pollution/quality index. It transforms large quantities of air quality data into a single number which summarize different quality parameters. Air Pollution Indices (APIs) are commonly used to indicate the level of severity of air pollution to the public. The Pollution Standards Index (PSI) was initially established in response to a dramatic increase in the number of people suffering respiratory irritation due to the deteriorating air quality. The PSI was subsequently revised and implemented by the USEPA in 1999, and became known as the Air Quality Index (AQI)” (Cheng et al., 2007).

Cairncross et al. (2007) reported that a “number of countries and territories (including the United Kingdom, the United States of America, Belgium, France, Spain, Finland, Sweden, Canada, Mexico, Australia, New Zealand, Hong Kong, Singapore, Malaysia, Thailand, China, Macau, Indonesia, Taiwan) use an API, usually applied at the urban scale, to communicate air quality. In the majority of examples, the API is based on the ambient concentrations of common pollutants such as SO_2, PM_{10}, NO_2, CO and O_3. In a few cases $PM_{2.5}$” is considered in the calculation of the index.

One of the most used API development systems is the US EPA system. The AQI includes “indices for O_3, PM, CO, SO_2 and NO_2. For each pollutant, ambient concentrations are related to index values on a scale from 0 to 500, representing a very broad range of air quality, from pristine air to pollution levels that present an imminent and substantial endangerment to the public. The index is normalized by defining an index value of 100 as that corresponding to the primary National Ambient Air Quality Standard for each pollutant, and an index value of 500 as the ‘significant harm level’” (EPA 2010/a, Cairncross et al., 2007).

The AQI measures daily pollution index of the pollutants for which EPA has established National Ambient Air Quality Standards (NAAQS). The index combines the NAAQS with an epidemiological function to determine a descriptor of human health effects due to short-term exposure to each pollutant. The index for a pollutant is calculated using the mathematical expression (Bishoi et al., 2009):

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{LO}) + I_{Lo} \qquad (2.15)$$

where I_p=the index value for pollutant, P; C_p=the truncated concentration of pollutant, P; BP_{Hi}=the breakpoint that is $\geq C_p$; I_{Hi}=the AQI value corresponding to BP_{Hi}, I_{Lo}=the AQI value corresponding to BP_{Lo}.

The indexes for each of the pollutants NO_2, O_3, PM_{10}, CO and SO_2 were obtained from Equation 2.15 using their respective break points and associated AQI values. Having calculated I_p of each pollutant, the EPA AQI is evaluated by considering the maximum index value (I_p) of the single pollutant. EPA determines the index number on a daily basis for each of the five pollutants, then reports the highest of the five figures and identifies which pollutant corresponds to the figure that is reported as the day AQI (Kyrkilis et al., 2007).

Murena (2004) carried out a study in order to develop a modified version of AQI of EPA "taking into consideration the limit values ruling in Europe. Air quality is monitored by a network of nine fixed stations measuring conventional pollutants. With respect to EPA AQI five categories (unhealthy, unhealthy for sensitive groups, moderate pollution, low pollution, good quality) are defined instead of six, and conditions corresponding to concentration levels lower than limit values are described by two categories instead of only one. The reference scale assumed values in the range 0–100". The evaluation of AQI is carried out by linear interpolation of the reference scale. Finally, urban air pollution index is calculated by Equation 2.16.

$$UPI = \sum_{s=1}^{m} PI_s W_s \qquad (2.16)$$

where UPI=urban air pollution index; PI=pollution index; PI_s=PI at site s, W_s=weight. As seen in Equation 2.16, it is as same as weighted linear sum aggregation function as mentioned in previous paragraphs.

Most of the time one single index, only water or only air quality index, is not sufficient to determine the situation. “To tackle with this problem, environmental quality index (EQI) is developed. Traditionally, an EQI is an algorithm that expresses a measurement of the environment’s qualitative state. The final result usually is a unique symbol or a simple combination of numerical and alphanumerical variables. It is a simplified expression of a complex combination of several factors and its relevance depends on its reliability and the quantity of information it provides. Most EQIs use parameters, weightings, rating curves, and aggregation methods” (Pykh *et al.*, 2000).

Zaharia and Surpateanu (2006) described the environmental impact assessment procedure using the method of global pollution index. The case study for environmental impact assessment was a heat and power co-generation plant, where the important emissions are in air and surface water, and rarely in soil. The magnitude of potential pollution generated by heat and power cogeneration plant was established based on the physico-chemical analysis concerning specific air pollutants (e.g., SO_2, NO_x, CO, solid particles), specific water pollutants (e.g., suspended solids, extractible substances, organic matter as BOD_5, chloride, sulphate), specific pollutants of soil (e.g., pH, extractible substances, total organic carbon (TOC)). Those data were further considered to appreciate the environmental impact assessment using the global pollution index of the study.

The assessment of environment quality into the industrial site is done for air, water and soil quality. Afterwards, made correlations based on graphics and assessment by global pollution index (Zaharia and Surpateanu, 2006). The calculation of global pollution index (I_{GP}) is done as in Equation 2.17 (Rojanschi, 1991; Macoveanu, 2005; Robu *et al*., 2005; Zaharia and Surpateanu, 2005 in Zaharia and Surpateanu, 2006):

$$I_{GP} = \frac{S_i}{S_r} \tag{2.17}$$

where: S_i is the area of the ideal state of environment, and S_r is the area of the real state of environment.

The consideration of area for the ideal and real state of environment (e.g., a triangle for *n*=3 environmental components) and global pollution index is done as follows (Equations 2.18-2.20) (Popa et al., 2005).

$$S_{ideal} = \frac{1}{2} \times \sin\left(\frac{360°}{n}\right) \times n \times b_{\max}^2 ; (b_{\max} = 10) \tag{2.18}$$

$$S_{real} = \frac{1}{2} \times \sin\left(\frac{360°}{n}\right) \times \left[b_1 \times b_n + \sum_{i=1}^{n-1} b_i \times b_{i+1} \right] \tag{2.19}$$

$$I_{GP} = \frac{S_{ideal}}{S_{real}} = \frac{n \times b_{\max}^2}{b_1 \times b_n + \sum_{i=1}^{n-1} b_i \times b_{i+1}} = \frac{100 \times n}{b_1 \times b_n + \sum_{i=1}^{n-1} b_i \times b_{i+1}} \tag{2.20}$$

where *n* denotes the number of environmental components and b_i is the evaluation degree corresponding to the environmental components (Zaharia and Surpateanu, 2006).

The same procedure as for global pollution index was applied for the improved method (Rojanschi, 1997; Macoveanu, 2005; Popa et al., 2005; Zaharia and Surpateanu, 2006). Firstly, it has to be established an evaluation scale for each studied environmental component, considering the maximum allowable concentrations of quality indicators, and after it has to be calculated the global pollution index with Equation 2.21. The authors of the improved method of global pollution index follow the concentric circles graphical methodology (Popa *et al.*, 2005 in Zaharia and Surpateanu, 2006) proposing a scale of the arithmetic mean values for the evaluation degrees, correlated with the global state of the environment. Thus, the environmental state can be assessed using the improved index of global pollution calculated as the arithmetic mean of evaluation degrees (b^2) using Equation 2.21 (Zaharia and Surpateanu, 2006).

$$I_{GP}^{*} = \frac{100}{b^2} \tag{2.21}$$

The improved method of global pollution index defines I_{PG} as a ratio between the surfaces of the concentric circles that corresponds to the ideal and real states of the environment in accordance with Eqution 2.21 (Popa et al., 2005; Petruc et al., 2006; Zaharia and Surpateanu, 2006). They proposed a case study of environmental impact assessment applied for a private company that produces basic chemical organic products using the alternative method of global pollution index. That study considers the gaseous emissions from the building of production sector into air (e.g., different sources at the outside production building with continuous or discontinuous gaseous emissions), the final effluent discharged directly into a river, as the most important emissions into environment and no emissions on soil/subsoil.

The magnitude of the potential pollution generated by the private company was established based on the physicochemical analysis (Murarasu, 2006 in Zahira and Muraşanu, 2009) concerning: i) specific air pollutants (e.g., SO_2, NO_x, CO, solid particles, having significant impact on air quality around the thermal plant and dispersion chimneys); ii) specific water pollutants (e.g., suspended solids, extractible substances into organic solvent, organic matters as COD and BOD_5, sulphides and H_2S, total iron, total residues) having significant impact on surface water quality around the discharging point of final combined effluent into a river (Zahira and Muraşanu, 2009).

In the process of assessment of environmental pollution one dimensional aggregated indicators are needed. Ludwig and Tulbure (1996) presented "an environmental pollution index concerning air and water pollution. This pollution index is aggregated from two components, the air pollution index and the water pollution index. The Environmental Pollution Index (EPI) is an aggregated coefficient integrating two principal aspects: one component which includes the air pollution and a second component which takes into account the water pollution. It could be also named Air and Water Pollution Index (AWPI). Very interesting in this context is the aggregation problem between the two levels in order to obtain a unique number to characterize the overall pollution". This aggregation process will be made using different methods (Ludwig and Tulbure, 1996).

The API itself is to be calculated with the following relation (Tulbure and Ludwig, 1995 in Ludwig and Tulbure, 1996):

$$API(x,y,z,t) = \frac{1}{\sum_i w_i} \times \sum_i \frac{C_{real,i}(x,y,z,t) \times w_i}{C_{ref,i}} \qquad (2.22)$$

where $C_{real,I}(x,y,z,t)$=existing values of pollutants concentrations at a certain place and time [ppm or mg/m^3]; $C_{ref,i}$=reference values: admissible values of pollutants concentrations [ppm or mg/m^3]; and w_i=weight coefficients.

The "WPI is defined in another way compared to API. WPI is completely fuzzy defined, which is due to the way how the admissible limits of certain pollutants in water are expressed in literature. The basic criteria, which determine WPI are the pollutants itselfs, in this case four pollutants: chloride, oxygen content, BOD, and TOC. They are defined as linguistic variables with the linguistic terms small, medium, and high" (Ludwig and Tulbure, 1996).

The problem when determining the AWPI is the aggregation of the two components of this index. It is possible to build mean values, as for instance arithmetic mean, geometric mean, harmonic mean, or root mean square. Ludwig and Tulbure (1996) proposed two aggregation methods based on linguistic interpretation and again on Fuzzy Logic (Ludwig and Tulbure, 1996).

"Using the fuzzy method the two components API and WPI as inputs as well as the output AWPI are defined as linguistic variables with the nine linguistic terms *very very small, very small, small, small medium, medium, high medium, high, very high, and very very high.* The membership functions are shaped triangular and at the edges trapeziform. All variables are defied on the interval [0, 1]" (Ludwig and Tulbure, 1996).

For instance, when a system has the values API high and WPI small, then the assigned AWPI will be medium. To obtain a numerical expression for AWPI in this case the following equation is used (Ludwig and Tulbure, 1996):

$$AWPI = \sqrt{API^2 + WPI^2} \qquad (2.23)$$

The aggregation to the AWPI "was obtained using two methods: a linguistic interpretation and a Fuzzy Logic based method. Both methods permit verbal classification of pollution levels. The presented EPI can be extended for the soil pollution too, obtaining in this way a complete environmental pollution index" (Ludwig and Tulbure, 1996).

Pykh *et al.* (2000) reviewed and compared "several different approaches to developing EQIs within a systems perspective: structural-regression models, thermodynamic-type models, diagram models, and complex systems simulation models. Obviously, this is only a conditional classification of models that might be used to link EQIs".

Butter and Eyden (1998) applied the methodology "for the construction of a composite overall index for environmental policy in the Netherlands by means of aggregation of the annual time series data collected by Adriaanse on seven theme indicators of environmental policy. The results from the European Omnibus Survey of opinion polls on concern with environmental problems are used to determine the aggregation weights" (Butter and Eyden, 1998).

The "first set of assumptions for the aggregation weights relate to the transformation of the 14 environmental policy problems of the European Omnibus Questionnaire to the seven themes of environmental policy in The Netherlands, which become part of the overall index. Next it has to be decided which results from the European Omnibus Survey that is used for composing the weights of the Dutch index. Application of the transformation key to these results and normalization gives the weights for basic version of the index" (Butter and Eyden, 1998).

Kang *et al.* (2002) emphasized the "need to construct a composite environmental index (CEI), and intend to construct an annual CEI for Korea. Nine types of problems were examine: greenhouse effect, ozone layer depletion, acidification, eutrophication, ecotoxication, natural resource depletion, photo-oxidation, loss of biodiversity, and noise-vibration-odour. In total, 37 indicators (CO_2, CH_4, CFC11, CFC12, CFC13, CFC114, 115, Halon 1211, Halon 1301, 111-TCE, SO_x, NO_x, NO_x, nutrient use, wastewater effluent, heavy metal, As, Cr, Ni, Pb, Cd, Hg, Zn, pesticides, specified waste, toxic chemicals, underground water, energy, fisheries, forest lumbering rate, HC, NO_x, land use, toxicology emission, noise, vibration, bad odour, traffic quantity, airplane noise) are considered. The weights of each problem are obtained from opinions of the environmental experts. Then, the sub-indices are integrated with their own weights" (Kang *et al.*, 2002).

By adding all the pressures of pollutants, a sub-index for each environmental problem is, finally, derived as shown in equation Equation 2.24 (Kang *et al.*, 2002):

$$SI_{jt} = P_{1jt} \times E_{1jt} + P_{2jt} \times E_{2jt} + \cdots + P_{njt} \times E_{njt} = \sum_{i=1}^{n} P_{ijt} \cdot E_{ijt} \qquad (2.24)$$

where SI_{jt} is sub-index for problem j in year t, P_{ijt} is emission of pollutant i causing problem j in year t, and E_{ijt} is environmental-impact coefficient of pollutant i causing problem j in year t. "For a specific problem emissions of some pollutants may be expressed in different units of measure. So, it is necessary to normalize the sub-index by dividing the amounts of each pollutant in comparative years by those emitted in a reference year. The environmental- impact coefficient is also replaced by the weighted value with its corresponding amount of pollutant". A normalization process is as follows (Kang *et al.*, 2002):

$$NI_{jt} = \frac{P_{1jt}}{P_{1j0}} \times EW_{1j} + \frac{P_{2jt}}{P_{2j0}} \times EW_{2j} + \cdots + \frac{P_{njt}}{P_{nj0}} \times EW_{nj} = \sum_{i=1}^{n} \frac{P_{ijt} \cdot EW_{ij}}{P_{ij0}} \qquad (2.25)$$

where NI_{jt} is normalized sub-index for problem j in year t and $Pij0$ is emission of pollutant i causing problem j in a reference year. EW_{ij} is weighted value of E_{ij}.

When aggregating normalized sub-indices, four types of forms are generally used: linear-sum, weighted-sum, root sum power (RSP), and root mean square (RMS) (Ott, 1978). The general forms of RSP and RMS are $(\sum_j NI^m{}_j)^{1/m}$ and $(\sum_j NI^m{}_j/n)^{1/m}$, respectively, where m is the number of environmental problems (m>1) (Kang *et al.*, 2002).

Kang *et al.*, (2002) adopted the weighted-sum form. The weights by environmental problem are calculated by dividing the arithmetic mean value of pairwise comparison for each row by the sum of values of pair wise comparison in a corresponding column (Kang *et al.*, 2002).

$$W_1 = \left(\frac{V_1}{V_1} \Big/ V_{T1} + \frac{V_1}{V_2} \Big/ V_{T2} + \cdots + \frac{V_1}{V_m} \Big/ V_{Tm} \right) \Big/ m$$

$$W_2 = \left(\frac{V_2}{V_1} \Big/ V_{T1} + \frac{V_2}{V_2} \Big/ V_{T2} + \cdots + \frac{V_2}{V_m} \Big/ V_{Tm} \right) \Big/ m \quad (2.26)$$

$$\vdots$$

$$W_m = \left(\frac{V_m}{V_1} \Big/ V_{T1} + \frac{V_m}{V_2} \Big/ V_{T2} + \cdots + \frac{V_m}{V_m} \Big/ V_{Tm} \right) \Big/ m$$

where W_j is the weight of *jth* problem; V_l/V_k is the value of pairwise comparison for k^{th} and l^{th} problems; V_{Tj} is the sum of values of pair wise comparison in j^{th} column. Finally, a CEI is calculated as follows (Kang *et al.*, 2002):

$$CEI_t = NI_{1t} \times NI_{2t} \times W_{2t} + \cdots + NI_{jt} \times W_{jt} + \cdots + NI_{mt} \times W_{mt} = \sum_{i=1}^{m} NI_{it} \cdot W_{it} \quad (2.27)$$

Where W_j is a major and direct influence on CEI, which represents how much each sub-index increases the composite index.

2.2. LEGISLATION

Legislation is defined as "*making or giving of laws; specifically : the exercise of the power and function of making rules that have the force of authority by virtue of their promulgation by an official organ of the state*" (IEEE, 2010).

In Turkey, there are different legislative instruments such as laws and regulation. The water quality and management regulated especially with the Law No. 2872 on Environment (Official Gazette (OG): 11 August 1983, no 18132) and regulations which have been approved with respect to above mentioned law. The regulations related with water quality which are published by MoEF are as follow (ÇYGM, 2010):

- Regulation on Water Pollution Control (OG: 31.12.2004 / 25687)

- Regulation of The Protecting of Waters Against Pollution by Nitrates From Agricultural Sources (OG: 18.02.2004 / 25337)
- Regulation of the Water Quality on Human Consumption (OG: 17.02.2005 / 25730)
- Regulation of the Quality Required of Surface Water Intended for the Abstraction of Drinking Water (OG: 20 .11.2005 / 25999)
- Regulation on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment (OG: 26.11.2005 / 26005)
- Regulation on the Urban Waste Water Treatment (OG: 08.01.2006 / 26047)

Regulation on Water Pollution Control was published on the Turkish Official Gazette dated 04.08.1988 and numbered 19919 and it was revised in 2004 and published on the Official Gazette dated 31.12.2004 and numbered 25687. The regulation became effective in order to bring out the technical and legal principles required for the determination of Water Pollution Control Principles with the purpose of actualizing utilization of the country's water resources potential protection, ensuring maximum optimized use and prevention of water pollution in harmony with the economic and social development objectives.

The purpose of the revised regulation is to set out principles for classifying ground and surface water quality in three and four classes, respectively. It also provides for water quality planning. This Regulation aims at both conserving the quality of water resources in ecosystems and protecting and improving water quality to meet national requirements. It prescribes protection zones and land use strategies in regard to reservoirs and lakes used for drinking water. Principles for discharging effluent to ground and surface waters, and for treating waste water, are also contained in the regulation (OG. 31.12.2004 / 25687).

According to the Regulation on Water Pollution Control, "Class I: High-Quality Water" is defined as water that may be used for the following purposes:

- Drinking water support with only disinfection,

- Recreational aims (with body touch as swimming),
- Trout growing,
- Animal growing and farm requirement,
- Other aims.

The quality criteria on the basis of inland water sources classes according to mentioned regulation is given in Appendix A. Regulation on Water Pollution Control also gives criteria for control of eutrophication in lakes. The regulation reads that "*for eutrophication control of lake, small lake and dam reservoirs, and receiver environment standards*" which are given in Appendix B.

In addition, studies of MoEF "related to prevention of water pollution and sustainable usage have been continuing at national and international level, European Union (EU) negotiation process has accelerated the studies. In the stage of participation to EU, adaptation studies of EU regulation to Turkish regulation have been started in 2000 and continuing. Although there are lots of regulation related to water and water management, the requirements of EU Water Directives could not be met by these regulations. Adaptation studies to EU Directives on water have been continuing" (Şahin et al., 2010).

Some key EU directives that deal with water quality are as follows (Ukmarinesac, 2010; Environmentlaw, 2010):

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

A range of inconsistent European legislation covers different aspects of water management. "The Water Framework Directive (WFD) aims to introduce a simpler approach which will result in greater protection. WFD looks at the ecological health of surface water bodies, as well as achieving traditional chemical standards. In particular it will help deal with diffuse pollution which remains a big issue after improvement of most point source discharges” (EAUK, 2010).

The Directive emphasizes that water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such; and defines its purpose is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater (OJEU, 2000).

The new Directive represents an ambitious and innovative approach to water management. “Key elements of the legislation include (EC, 2002):

- The protection of all waters - rivers, lakes, coastal waters and groundwaters.
- The setting of ambitious objectives to ensure that all waters meet “good status” by 2015.
- The requirement for cross border co-operation between countries and all involved parties.
- Ensuring the active participation of all stakeholders, including NGOs and local communities, in water management activities.
- Requiring water pricing policies and ensuring that the polluter pays.
- Balancing the interests of the environment with those who depend on it.”

In terms of pollution control, the WFD combines two approaches; the best possible reduction of emissions and a minimum quality threshold, and to ensure that the objectives of “good ecological quality” of water are met by 2015 (EC, 2002, 2010/f).

The WFD offers river basin management as a single system of water management, instead of according to administrative or political boundaries. While several Member States already take a river basin approach, this is not the case for whole. For each river basin a “river basin management plan” will need to be established and updated every six years (EC, 2010/g).

Council Directive 80/778/EEC of 15 July 1980 relating to the quality of water intended for human consumption as amended by Council Directives 81/858/EEC and 91/692/EEC (further amended by Council Regulation 1882/2003/EC).

The objective of the Drinking Water Directive is to protect the health of the consumers in the European Union and to make sure the water is wholesome and clean (OJEU, 1980). The Directive

- Sets quality standards for drinking water quality at the tap (microbiological, chemical and organoleptic parameters) and the general obligation that drinking water must be healthful and clean,
- Obliges Member States to regular monitoring of drinking water quality and to provide to consumers adequate and up-to-date information on their drinking water quality,
- Member States may exempt water supplies serving less than 50 persons or providing less than 10 m^3 of drinking water per day as an average and water in food-processing undertakings where the quality of water cannot affect the wholesomeness of the foodstuff in its finished form (EC2010/c).

Drinking Water Directive sets standards for the most common substances which can be found in drinking water to ensure healthy drinking water throughout European Union. According to the Directive a total of 48 microbiological and chemical parameters must be monitored and tested regularly. In the Directive, World Health Organization (WHO) guidelines for drinking water are used as a basis for the standards (OJEU, 1980).

Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources

The purpose of this Directive is to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution. (OJEU, 1991).

Some of the other water-related directives of EU are as follow:

- Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC)
- The Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community
- Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment
- Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. (Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration.)

Legislation developed by the European Union establishes definitions, standards and objectives for a number of pollutants in water in water quality related directives particularly "Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy" and "Council Directive 80/778/EEC of 15 July 1980 relating to the quality of water intended for human consumption as amended by Council Directives 81/858/EEC and 91/692/EEC (further amended by Council Regulation 1882/2003/EC)". These definitions, standards and objectives are given in the tables given in Appendix C and D.

Another topic to be discussed in this study is air quality. In Turkey, there are different legislative instruments such as regulations for air quality assessment and management. The air quality and management regulated especially with the Law No. 2872 on Environment (Official Gazette: 11 August 1983, no 18132) and regulations which have been approved with respect to above mentioned law. The regulations related with air quality which are published by MoEF are as follow (ÇYGM, 2010):

- Regulation on Assessment and Management of Air Quality (OG. 06.06.2008/26898)
- Regulation on Control of Industrial Air Pollution (OG. 03.07.2009/27277)
- Regulation on Control of Exhaust Gases (OG. 04.04.2009/27190)
- Regulation on Control of Air Pollution from Heating (OG. 13.01.2005/25699)
- Regulation on Substances Damaging Ozone Layer (OG. 12.11.2008/27052)
- Regulation on Quality Gasoline and Diesel Fuel (OG. 11.06.2004/25489)

The Regulation on Assessment and Management of Air Quality (OG: 06.06.2006/26898) sets forth principles and objectives concerning air quality so as to avoid or reduce harmful effects on human health and the environment as a whole. It lays down provisions governing the assessment of air quality on the basis of defined methods and criteria. Furthermore, it defines procedures to obtain adequate information on air quality and ensure that it is made available to the public by means of alert thresholds. MoEF and its provincial directorates will conduct preliminary assessment of the air quality. Details regarding the assessment of the air quality are given in the Regulation. The MoEF shall take all necessary measures to ensure the threshold values indicated in these provisions. The Ministry and its provincial directorates will classify the zones and subzones in accordance with the level of pollutants, whether such pollutants exceed the threshold values or remain within the threshold values or below such values.

The Regulation on Assessment and Management of Air Quality has been prepared in compliance with the provisions of the EU Directives 96/62/EC, 99/30/EC, 2000/69/EC, 2002/3/EC and 2004/107/EC (OG: 06.06.2008 / 26898), and sets standards and objectives. The long term objectives, target values, limit values, public information and alert thresholds, and margin of tolerance are mentioned in

Annex-I of the Directive. Limit values, public information and alert thresholds are given in Appendix E.

In EU, there are various legislation on air quality and management, since humans can be adversely affected by exposure to air pollution. In order to establish health based standards and objectives for number of pollutants in air, the European Union has developed an extensive body of legislation (EC, 2010/h).

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Air Quality Framework Directive)

The Directive includes the following elements (OJEU, 2008):

- The merging of most of existing legislation into a single directive with no change to existing air quality objectives.
- New air quality objectives for $PM_{2.5}$ including the limit value and exposure related objectives – exposure concentration obligation and exposure reduction target.
- The possibility to discount natural sources of pollution when assessing compliance against limit values.
- The possibility for time extensions of three years (PM_{10}) or up to five years (NO_2, benzene) for complying with limit values, based on conditions and the assessment by the European Commission.

“European legislation on air quality is built on certain principles. The first of these principles is that the Member States divide their territory into a number of zones and agglomerations. In these zones and agglomerations, the Member States should undertake assessments of air pollution levels using measurements and modeling and other empirical techniques. Where levels are elevated, the Member States should prepare an air quality plan or programme to ensure compliance with the limit value before the date when the limit value formally enters into force. In addition, information on air quality should be disseminated to the public" (EC, 2010/h).

In addition to Air Quality Framework Directive there are various source of EU legislation about ambient air quality, stationary source emissions, volatile organic compounds (VOCs), national emission ceilings, and transport and environment (EC, 2010/i).

Legislation developed by the European Union establishes health based standards and objectives for a number of pollutants in air in air quality related directives particularly "Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe" and "Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air". These standards and objectives are given in the tables given in Appendix F.

2.3. SEYHAN BASIN

The Seyhan River Basin is located in the Eastern Mediterranean Region of Turkey (Figure 2.1), between latitudes 36° 30' and 39° 15' North, and longitudes 34° 45' and 37° 00' East. The basin covers an area of 21.139 km^2. Most part of the basin is located in the province borders of Adana and Kayseri. Very minor parts of Sivas, Kahramanmaraş and Niğde provinces are also in the area of the basin. The physiography of the Seyhan Basin varies from south to north, the lowlands characterizing the south while the north is represented by harsh topography The Seyhan Basin is bordered with Tecer Mountains (1600 m) on north, Tahtalı Mountains (3075 m) on east, Melendiz and Bolkar Mountains (3524 m) on west, and Mediterranean on south. The map of the Basin and its location in Turkey is given in Figure 2.1.

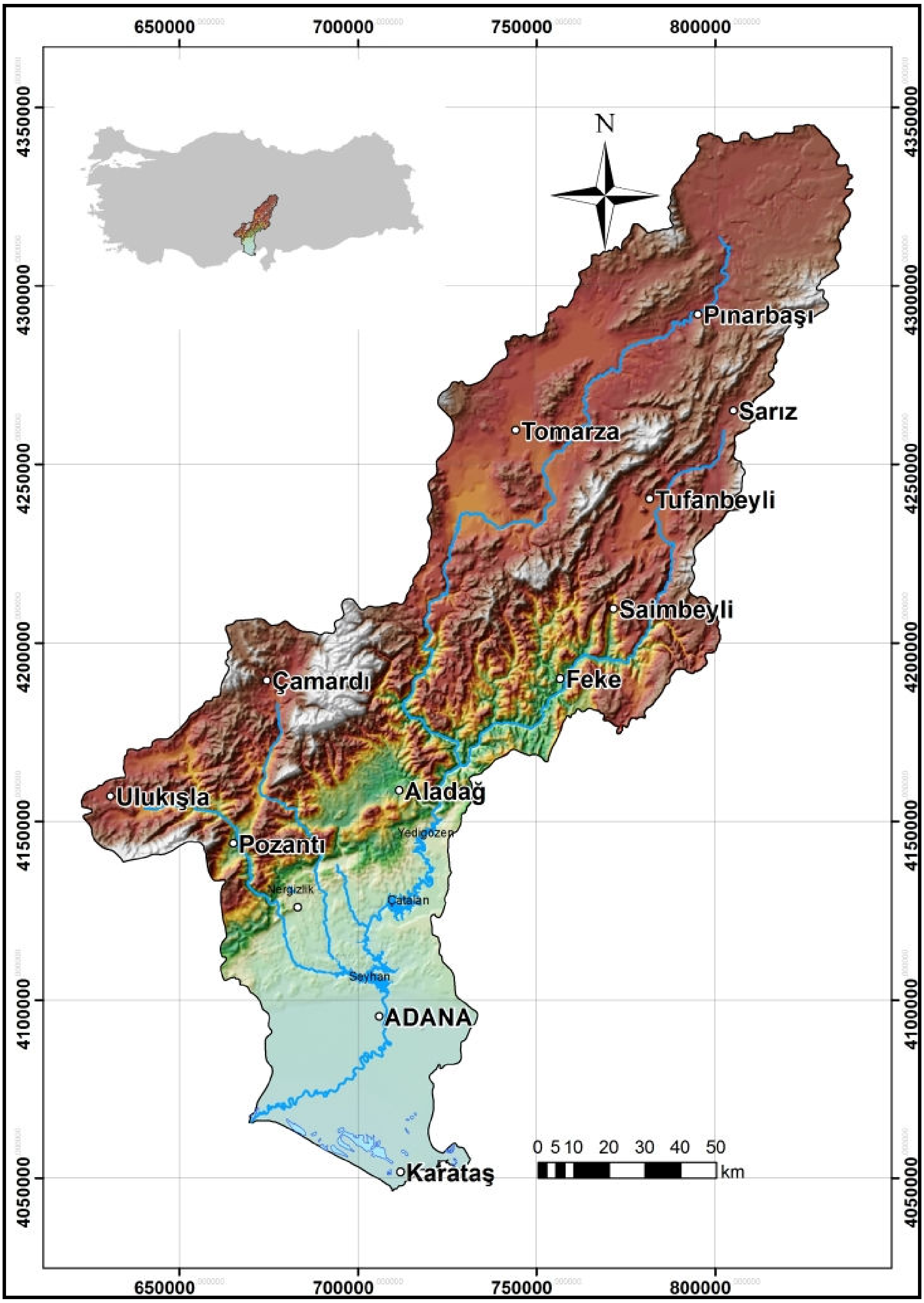

Figure 2.1. Seyhan Basin and Its Location in Turkey

Seyhan River is formed of two river systems: "Zamantı River" (length 306 km), which originates in the eastern section of Central Anatolia (Uzunyayla region), and further to the east "Goksu River" (length 199 km), which originates in Eastern Anatolia. The main tributaries of Seyhan River include Eğlence, Körkün, Üçürge and Çakıt streams (Waterforum, 2010). Seyhan Basin might be divided into two catchments as Upper and Lower Seyhan Catchments. The border of these catchment areas passes between the Göktaş Dam on Zamantı River and Berke Dam and Köprü district on Göksu River. The altitude of this border on Zamantı tributary is 490 m. and on Göksu tributary is 525 m. (Megar, 2009).

Upper Seyhan Catchment has generally mountainous territory. Tahtalı Mountains cuts the catchment in the southwest-northeast direction. The biggest plains in the catchment are the plains at Uzunyayla on north and 1500 m. altitude plains on west. In addition, there various plains in the valleys of Zamantı and Göksu rivers, which are the two main rivers in the basin. The length of Zamantı from its source to joining point with Göksu, called Kavşak, is 306 km and the drainage area is 8.748 km^2. The length and drainage area of Göksu is 199 km and 4.300 km^2, respectively (Megar, 2009).

The catchment area with mountainous territory from the estuary of Seyhan River on the Mediterranean with the altitude of zero to the biggest plain in the catchment is Lower Seyhan plain which lays from Seyhan Dam to the Mediterranean. The main rivers Seyhan formed from the unification of Zamantı and Göksu rivers that collect the water of upper catchment. The length of Seyhan River from the unification point to the sea is 191 km, and the important tributaries from Kavşak to Seyhan Dam are Doğançay, Eğlence, Körkün and Çakıt creeks (Megar, 2009).

In the basin, "the climate is strongly influenced by the topography. The Northern side of the basin has terrestrial components of Central Anatolian climate. This part has the precipitation around 350-500 mm. The highest precipitation occurs at the highlands of central Seyhan Basin, particularly around Aladağ region, is about 1500 mm. The region between coastal zone and Taurus Mountains characterized by dry and hot summers and rainy and warm winters and precipitation in the range of 600-800 mm is defined as a semi-arid 3rd degree meso-thermal, Mediterranean climate. Dominant soils of the forest stands are classified as Lithic Xerorthent of Entisol and developed on fluvial and lacustrine materials during the Oligocene Epoch" (Berberoğlu et al., 2008).

The population density in the Upper Seyhan cachment is not so high, only there are some small settlements in the borders of Kayseri. However, this region is rich in mining areas. Chrome is extracted from Pınarbaşı and its villages Karaboğaz, Büyükkaramoklu, Kılıçmehmet, Demircili and Yahyalı's villages Karaköy, Delialiuşağı; ferrous from Yahyalı-Karaköy, Feke, and Develi-Kaleköy; and lead and zinc from Yahyalı-Taşhan, Develi-Kaleköy, Havadan, and Ayşepınar (Megar, 2009).

The settlements in the lower Seyhan catchment are much bigger and population is much denser. Agricultural and industrial activities are very high in this region, and Adana, one of the biggest cities of Turkey, places in this catchment (Megar, 2009).

The basin remains in the borders of Adana, Kayseri, and Niğde Provinces, where the biggest part remains in the borders of Adana. The districts in the basin are city centre of Adana (Seyhan, Yüreğir, Çukurova, Sarıçam, and Karaisalı districts), Karataş, Pozantı, Aladağ, Feke, Saimbeyli, and Tufanbeyli districts of Adana, Tomarza, Sarız and Pınarbaşı districts of Kayseri, and Çamardı and Ulukışla districts of Niğde as shown in Figure 2.1. The populations of the mentioned cities are given in Table 2.2 (TUIK, 2010). The basic economic activity in the basin is agriculture. However, according to geographical conditions and various factors there is a variety in economical activities. This variety can be understood from population working in agriculture, industry, and service sectors (Megar, 2009). The sectoral range of labor in the Seyhan Basin is given in Table 2.3 (DPT, 2004).

Table 2.2. Population of cities in the Seyhan Basin (TUIK, 2010)

Province	District	Population (2009)
Adana	Seyhan	722.852
	Yüreğir	415.047
	Çukurova	327.460
	Sarıçam	90.879
	Karaisalı	7.307
	Karataş	8.504
	Pozantı	9.880
	Aladağ	4.269
	Feke	4.534
	Saimbeyli	3.952
	Tufanbeyli	5.512
Kayseri	Tomarza	10.191
	Sarız	4.290
	Pınarbaşı	11.534
Niğde	Çamardı	3.480
	Ulukışla	5.486

Table 2.3. The sectoral range (in %) of labor in the Seyhan Basin (DPT, 2004)

Province	District	Agriculture	Industry	Service
Adana	Seyhan	23.08	20.5	56.42
Adana	Yüreğir	23.08	20.5	56.42
Adana	Aladağ	85.31	2.65	12.04
Adana	Feke	89.06	1.86	9.08
Adana	Karaisalı	85.73	2.88	11.39
Adana	Karataş	81.58	3.09	15.33
Adana	Kozan	72.5	3.51	23.99
Adana	Pozantı	65.92	4.9	29.18
Adana	Saimbeyli	85.6	1.19	13.21
Adana	Tufanbeyli	84.79	2.35	12.87
Niğde	Çamardı	86.73	1.98	11.29
Niğde	Ulukışla	77.94	2.93	19.12
Kayseri	Pınarbaşı	81.55	4.07	14.38
Kayseri	Sarız	84.09	1.95	13.96
Kayseri	Tomarza	80,53	1,88	17,59

The geographical conditions of the basin and Adana provide many advantages for agriculture. However, if assessing labor data of metropolitan district Seyhan and Yüreğir, it can be seen that main sectors is service sector, and employment in agriculture and industry is almost equal (Table 2.3). Besides this district where non-agriculture sectors are dominant is Pozantı. It can be seen that, the districts with dominant agriculture sector are Karataş, Aladağ, Feke, Karaisalı, Saimbeyli, Tufanbeyli, Çamardı, Pınarbaşı, Sarız, and Tomarza (Megar, 2009)

More than half of the employment is in service sectors in all urban areas of the Seyhan Basin. The portion of agriculture is relatively low in almost all urban areas of the districts. Agriculture has an important role only in Karataş, Tufanbeyli, Çamardı and Sarız districts. The districts where industrial employment has significant role are Seyhan and Yüreğir. (Megar, 2009)

Besides its high population and industry, the basin also has rich biodiversity and various vulnerable areas. There are 1 national park (DKMP, 2010/a), 8 wildlife reserve sites (DKMP, 2010/b), and 3 internationally important wetlands (DKMP, 2010/c) where one of them (Akyatan Lake) is also a Ramsar Site. Names, provinces and area of the sites are given in Table 2. 4.

Table 2.4. Protected sites in the Seyhan Basin (DKMP, 2010/a, b, c)

Status	Site	Province	Area (ha)
National Park	Aladağlar	Adana, Kayseri, Niğde	54.524
Wildlife Reserve Site	Tuzla Lake	Adana	3.974
	Akyatan Lake	Adana	15.304
	Seyhan Dam	Adana	11.436
	Pozantı Karanfildağ	Adana	31.020
	Hançerderesi	Adana, Kahramanmaraş	7.894
	Tarsus Hopur Topaşır	Mersin	5.984
	Yahyalı Aladağlar	Kayseri	7.321
	Çamardı Demirkazık	Niğde	18.674
Internationally Important Wetland	Akyatan Lake	Adana	14.000
	Tuzla Lake	Adana	2.800
	Zamantı River	Kayseri	N/A

CHAPTER 3

METHODOLOGY

In this chapter, information about the data used in development of environmental quality/pollution index (EQI/EPI) and steps are given and explained. The first aim of the study is to develop a database that includes water and air quality parameters in addition to meteorological data and land cover classification. Water and air quality and meteorological data used in this study obtained from General Directorate of State Hydraulic Works (DSI), Ministry of Environment and Forestry (MoEF), and Turkish State Meteorological Service (DMI), respectively. Necessary images for land cover classification are obtained by MoEF, and classified in the MoEF as part of an EU project.

Data obtained from governmental agencies are transferred and processed via geographical information system software to observe the spatial distribution. First, Seyhan Basin is delineated. For delineation of the basin digital elevation model (DEM) produced from 1/250.000 scaled topographic maps are used. The basin is delineated from the DEM by computing the flow direction and using it in ArcGIS 9.3 software. Then, water and air quality parameters, as well as meteorological data and land cover and usage information, are entered.

In this study, water and air quality indices are developed for the selected stations and the selected years. WQI is calculated by using the method suggested by NSF, and AQI is developed according to the modified EPA's AQI. For development of both of the indices same procedure is followed. Selection of quality variables of concerns is followed by development of the sub-indices. Afterwards, the quality variables are weighted according to their relative importance; and finally sub-

indices are aggregated to produce an overall index. As aggregation method, weighted arithmetic mean function is selected for development of indices.
Of the indices, firstly WQI is developed by using the DSI water quality data. The parameters to be used in index development and their sub-indices and weights are decided according to NSF indexing method, which has wide acceptance. Afterwards, AQI is determined by using air quality data of MoEF. The air quality parameters are selected according to their importance and availability of the data for all monitoring stations. The sub-indices and weights of selected parameters decided according to the modified AQI of EPA, which is modified according to EU criteria.

Finally, combined environmental quality index (EQI) was generated for the locations where sufficient information was available. EQI was developed by two aggregation methods, one based on linguistic interpretation and the other again on weighted arithmetic mean function. For development of EQI, air quality data is interpolated by inverse distance weighted method, the one that gives the most suitable results, in order to obtain both water and air quality data at the selected monitoring stations. After interpolation of air quality data, WQI and AQI are calculated, followed by development of EQI by two aggregation methods. Finally, developed indices are classified according to their values.

In the following sections, information about the data used in development of environmental pollution index (EPI) and steps are given and explained.

3.1. DELINEATION OF SEYHAN BASIN

A basin is a part of land which is bounded by the water division line having a concave topographic form, where all of the water that is under it or drains off of it goes into the same place, such as a stream, lake, estuary, wetland, aquifer, or even the ocean (EPA, 2010/a). The focus of this study is the Seyhan Basin which is located in the eastern Mediterranean part of Turkey. In order to delineate the basin, first elevation contour lines are produced from 1/250.000 scaled topographic maps.

These data digitalized, and obtained in .shp format, format that can be used in ArcGIS software All the maps are in the geographical coordination system of ED 1950 UTM Zone 36 with European 1950 datum. In the study, ArcGIS 9.3 and ERDAS Imagine 8.5 softwares are used.

In order to delineate the basin digital elevation model (DEM), a raster representation of a continuous surface, usually referencing the surface of the earth (ESRI, 2010/a) produced from scaled topographic maps are used. The basin is delineated from the DEM by computing the flow direction and using it in the ‘Spatial Analyst Tools/Hydrology/Basin’ tool of the software ArcGIS 9.3. The Basin tool delineates drainage basins within the Analysis window by identifying ridge lines between basins. Basin analyzes the flow direction raster to find all sets of connected cells that belong to the same drainage basin. The drainage basins are created by locating the pour points at the edges of the Analysis window as well as sinks, then identifying the contributing area above each pour point. This resulted in a raster of the basins (ESRI, 2010/b). The basin screen of the software is given in Figure 3.1.

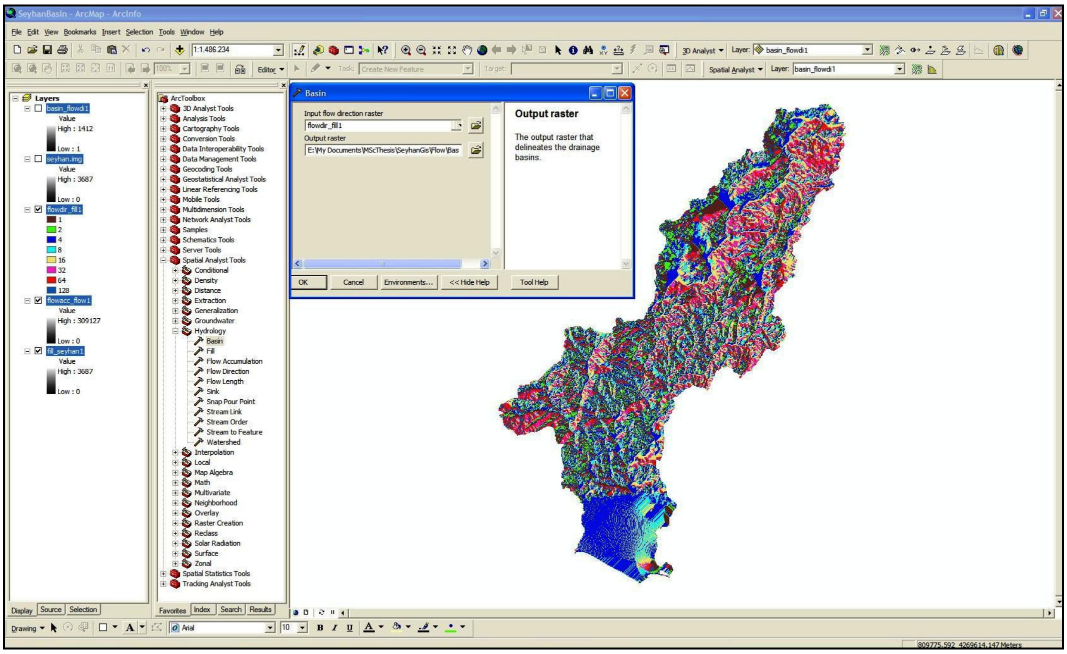

Figure 3.1. Screenshot of ArcGIS9.3 software

The flow accumulation threshold used to delineate the basin is produced by using the 'Spatial Analyst Tools/Hydrology/Flow Accumulation' function. When the threshold is used to define a watershed, the pour points for the watershed will be the junctions of a stream network derived from flow accumulation (Figure 3.2). Therefore, the flow accumulation raster is specified as well as the minimum number of cells that constitute a stream or the threshold value (ESRI, 2010/c).

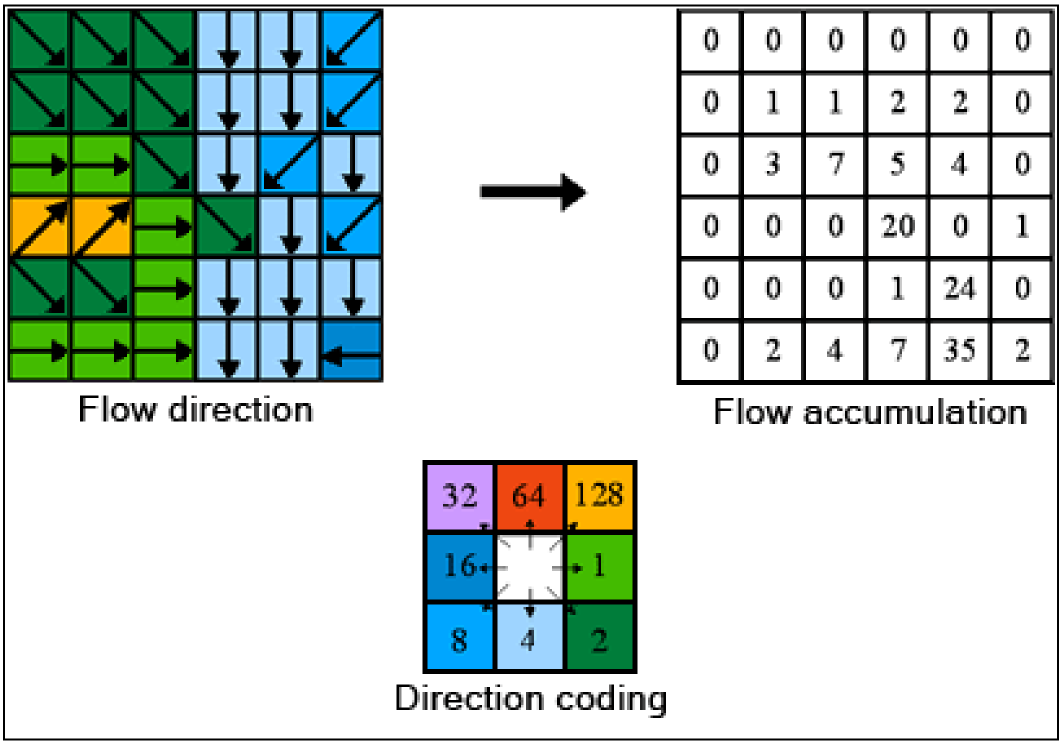

Figure 3.2. Determining the accumulation of flow

In the Figure 3.2., the top left image shows the direction of travel from each cell and the top right the number of cells that flow into each cell. Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels. Cells with a flow accumulation of zero are local topographic highs and may be used to identify ridges. The output from the 'Flow Accumulation' function would represent the amount of rain that would flow into each cell, assuming that all water became runoff (ESRI, 2010/d).

Afterwards, by using the output of 'Flow Accumulation' function, stream networks are delineated from the DEM again by using the functions under 'Spatial Analyst Tools/Hydrology'. Finally, all geographical and environmental data produced or obtained are added to the map produced in order to make analysis and show situation or results.

3.2. LAND COVER

While land cover is described as "observed (bio)physical cover on the earth's surface", and should be limited to describe vegetation and man-made features; land use is described as "arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it". Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment. Classification is "an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers defined it as the ordering or arrangement of objects into groups or sets on the basis of their relationships. A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes" (FAO, 2010).

Land cover is the observable vegetation, geologic, hydrologic or anthropogenic features on earth's land surface, and these features can be measured and categorized using satellite imagery (GLCF, 2010). In this study satellite images (Landsat-7 ETM, SPOT-4, IRS LISS III) containing the Seyhan Basin are obtained from MoEF to study land cover of the area. The satellite data are geometrically corrected to match the UTM map projection. Land cover data from field surveys and literature are collected for a random sample of areas (Table 3.1.). With the land cover data as reference material which describes spectral responses of known areas are generated and used to classify each pixel of the entire basin into one of the CORINE Land Cover Classification (CLCC). After classification, land cover of the basin is mapped.

The land cover classification system, CLCC, of the European environmental landscape based on interpretation of satellite images. CORINE stands for "Coordination of Information on the Environment". The EU established CORINE in 1985 to create pan-European databases on land cover, biotopes (habitats), soil maps and acid rain. In CLCC, there are five main classes and various sub-classes. The CORINE land cover classes are shown in Table 3.1 (EIONET, 2010).

Table 3.1. CORINE Land Cover Classes

CLC Code			**Class**
1			***Artificial surfaces***
	1.1		*Urban fabric*
		1.1.1	Continuous urban fabric
		1.1.2	Discontinuous urban fabric
	1.2		*Industrial, comercial and transport units*
		1.2.1	Industrial or commercial units
		1.2.2	Road and rail networks and associated land
		1.2.3	Port areas
		1.2.4	Airports
	1.3		*Mine, dump and construction sites*
		1.3.1	Mineral extraction sites
		1.3.2	Dump sites
		1.3.3	Construction sites
	1.4		*Artificial, non-agricultural vegetated areas*
		1.4.1	Green urban areas
		1.4.2	Sport and leisure facilities
2			***Agricultural areas***
	2.1		Arable land
		2.1.1	*Non-irrigated arable land*
		2.1.2	Permanently irrigated land
		2.1.3	Rice fields
	2.2		*Permanent crops*
		2.2.1	Vineyards
		2.2.2	Fruit trees and berry plantations
		2.2.3	Olive groves
	2.3		*Pastures*
		2.3.1	Pastures
	2.4		Heterogeneous agricultural areas
		2.4.1	*Annual crops associated with permanent crops*
		2.4.2	Complex cultivation patterns
		2.4.3	Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4	Agro-forestry areas

Table 3.1. CORINE Land Cover Classes (continued)

CLC Code			Class
3			***Forests and Semi-natural areas***
	3.1		*3.1.1 Broad-leaved forest*
		3.1.1	3.1.2 Coniferous forest
		3.1.2	3.1.3 Mixed forest
		3.1.3	3.2 Scrub and/or herbaceous vegetation associations
	3.2		*3.2.1 Natural grasslands*
		3.2.1	3.2.2 Moors and heathland
		3.2.2	3.2.3 Sclerophyllous vegetation
		3.2.3	3.2.4 Transitional woodland-shrub
		3.2.4	Forests
3			***Forests and Semi-natural areas***
	3.3		*Open spaces with little or no vegetation*
		3.3.1	Beaches, dunes, sands
		3.3.2	Bare rocks
		3.3.3	Sparsely vegetated areas
		3.3.4	Burnt areas
		3.3.5	Glaciers and perpetual snow
4			***Wetlands***
	4.1		*Inland wetlands*
		4.1.1	Inland marshes
		4.1.2	Peat bogs
	4.2		*Maritime wetlands*
		4.2.1	Salt marshes
		4.2.2	Salines
		4.2.3	Intertidal flats
5			***Water bodies***
	5.1		*Inland waters*
		5.1.1	Water courses
		5.1.2	Water bodies
	5.2		*Marine waters*
		5.2.1	Coastal lagoons
		5.2.1	Estuaries
		5.2.3	Sea and ocean

3.3. METEOROLOGICAL DATA

Meteorological data used is obtained from the DMI. Adana, Kayseri, Niğde, Tufanbeyli, Gülek, Pınarbaşı, Tomarza, Sarız, Ulukışla, and Karataş Meteorological Stations are chosen for this study. The coordinates and elevations of these stations are given in Table 3.2. Locations are also depicted in Figure 3.3. Although not directly used in EPI development, these data are input into the database in order to compile all available data that may impact environmental conditions in the area, which is one of the aims of the study.

Table 3.2. Meteorological Monitoring Stations

Code	Station	X (East)	Y (North)	Elevation (m)
6204	Tufanbeyli	248.545	4.227.461	1.350
7929	Gülek	631.481	4.109.210	950
17196	Kayseri	699.861	4.257.120	1.093
17250	Niğde	624.500	4.160.151	1.211
17351	Adana	695.761	4.097.135	20
17802	Pınarbaşı	259.080	4.257.135	1.500
17837	Tomarza	716.953	4.238.682	1.347
17840	Sarız	263.863	4.241.441	1.500
17906	Ulukışla	614.284	4.132.262	1.453
17981	Karataş	700.134	4.023.969	22

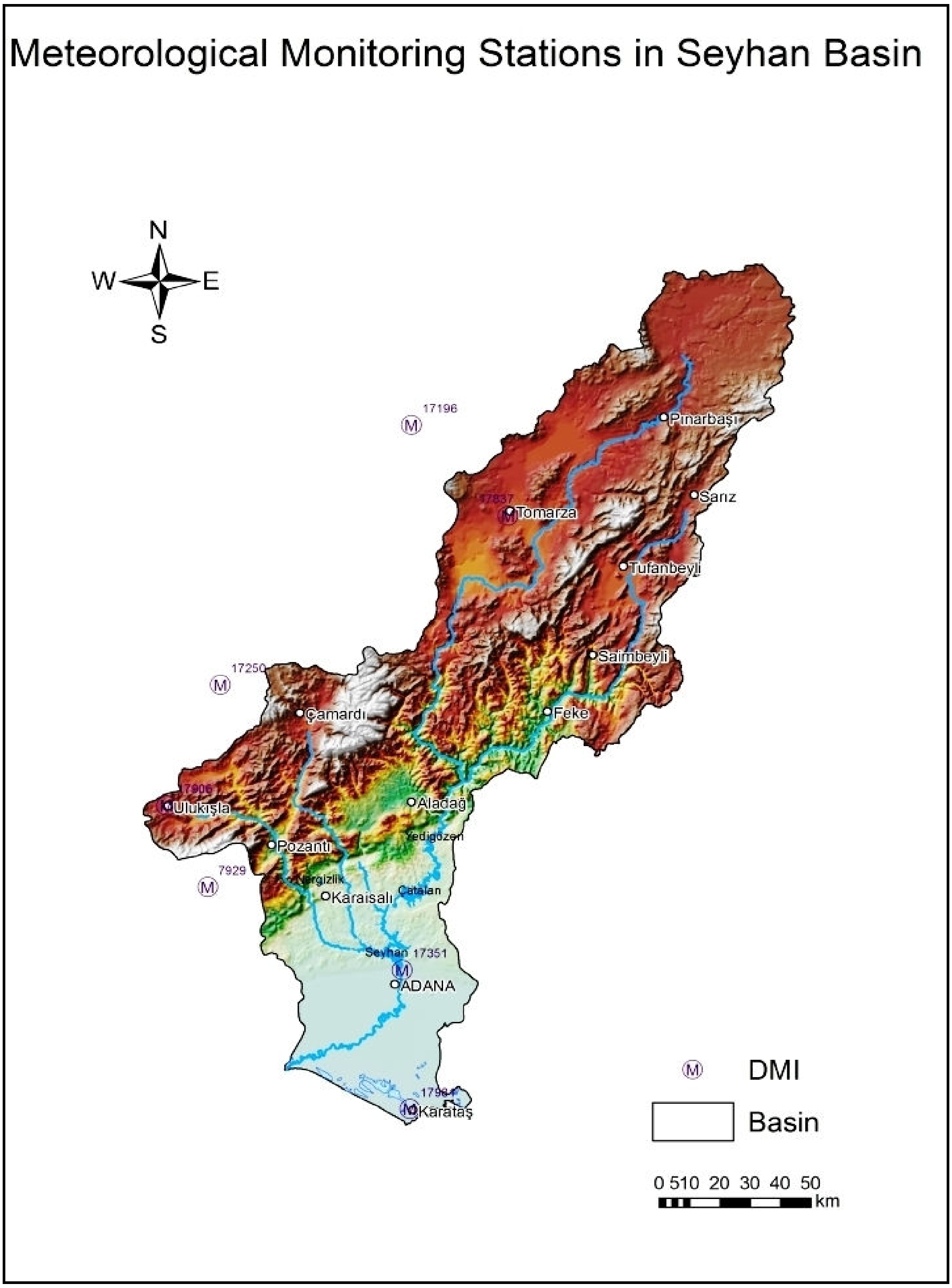

Figure 3.3. Meteorological Monitoring Stations

3.4. WATER QUALITY DATA

Water quality data is needed in order to determine EPI. For the entire Seyhan Basin the water quality data produced by DSI and General Directorate of Electrical Power Resources Survey and Development Administration (EIE) are used. In addition, data produced by MoEF for Akyatan and Tuzla Lagoons which are at lowest part of the basin are taken. The monitoring stations of DSI, EIE, and MoEF are given in Tables 3.3., and 3.4., respectively. The locations of the stations are depicted in Figure 3.4.

Table 3.3. Water Quality Monitoring Stations of DSI and EIE in Seyhan Basin

No.	River	Station	Coordinates		Altitude (m)
			X (East)	Y (North)	
DSI-1806	Çakıt	Şekerpınarı	665.075	4.148.575	800
DSI-1805	Körkün	Hacılı	690.991	4.129.927	255
DSI-1804	Seyhan	Taşköprü	707.901	4.095.398	25
DSI-1801	Seyhan	Eğner	718.597	4.139.945	190
DSI-1816	Üçürge	Nergizlik	681.792	4.130.244	400
DSI-1831	Zamantı	Göktaş	717.450	4.178.710	500
EIE-1805	Göksu	Gökdere	730.746	4.166.715	312
EIE-1818	Seyhan	Üçtepe	717.211	4.144.695	148
EIE-1820	Körkün	Hacılı	690.986	4.129.837	167
EIE-1822	Zamantı	Fraktin	729.837	4.236.354	1270
EIE-1825	Eğlence	Eğribük	694.208	4.137.497	222
EIE-1826	Zamantı	Ergenuşağı	727.538	4.171.809	360
EIE-1828	Çakıt	Salbaş	687.249	4.108.475	80

Table 3.4. Monitoring Stations of MoEF in Akyatan and Tuzla Lagoons

Akyatan			**Tuzla**		
#	***Coordinates***		**#**	***Coordinates***	
	X (East)	***Y (North)***		***X (East)***	***Y (North)***
A1	698.396	4.058.453	*T1*	682.143	4.063.421
A2	700.000	4.058.000	*T2*	679.477	4.066.533
A3	702.700	4.055.850	*T3*	682.038	4.065.046
A4	706.000	4.053.600	*T4*	684.032	4.063.877
A5	704.475	4.055.625	*T5*	685.347	4.062.466
A6	708.000	4.052.000	*T6*	686.074	4.061.550
A7	707.762	4.050.000	-	-	-
A8	711.040	4.051.259	-	-	-
A9	707.981	4.058.849	-	-	-

The water quality monitoring stations, which are used in this study, belongs to DSI, EIE, and MoEF are shown on Figure 3.4.

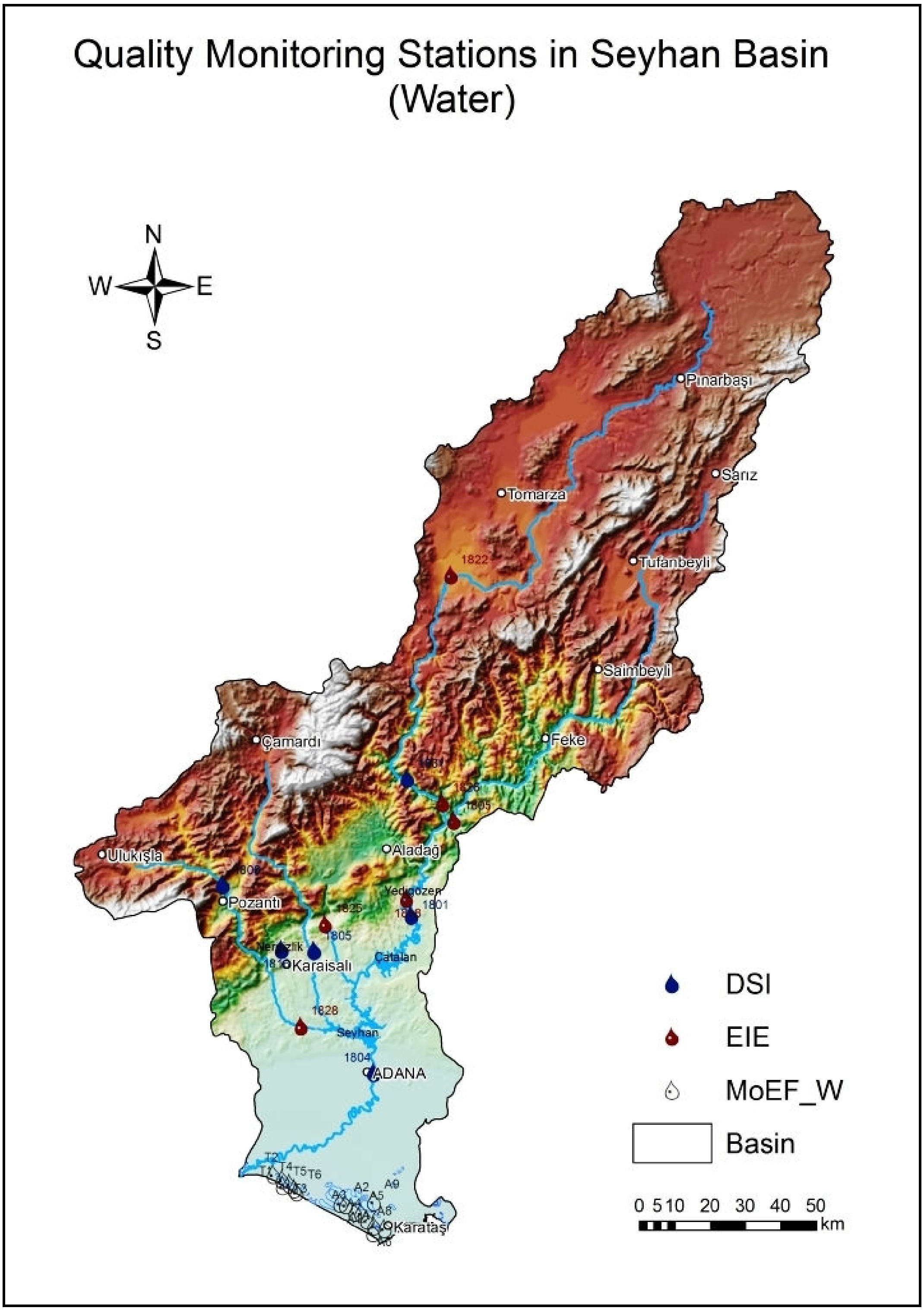

Figure 3.4. Water quality monitoring stations

3.5. AIR QUALITY DATA

In addition to water quality data, air quality data is also needed in order to determine EPI. In order to calculate EPI for the basin, air quality and the water quality at the same location should be determined. Since air and water quality observation stations are not situated in the same location, air quality at the water quality observation stations are derived as will be discussed later on. In order to achieve this derivation, air quality monitoring stations around the Seyhan Basin are used as well as the stations in the Basin. For the entire Seyhan Basin and its vicinity, the air quality data produced by MoEF are used for indexing. The locations of the air quality monitoring stations are given in Table 3.6 and Figure 3.5.

Table 3.5. Air Quality Monitoring Stations of MoEF in Seyhan Basin and Around

Station	Coordinates		Altitude (m)
	X (East)	Y (North)	
Adana-Çatalalan	700.781	4.117.915	98
Adana-Doğankent	709.188	4.081.234	10
Adana-Meteoroloji	708.531	4.097.872	22
Adana-Valilik	705.775	4.097.280	23
Aksaray	588.523	4.247.138	941
Hatay	248.899	4.004.504	104
Kahramanmaraş	317.093	4.162.252	613
Kahramanmaraş-Elbistan	341.177	4.229.808	1133
Kayseri	706.442	4.290.634	1058
Kayseri-Hürriyet	714.653	4.289.001	1052
Kayseri-Melikgazi	718.683	4.289.234	1063
Mersin	645.850	4.074.611	10
Nevşehir	648.245	4.275.553	1259
Niğde	647.864	4.203.453	1211
Osmaniye	254.146	4.105.876	120
Sivas	328.842	4.401.826	1285

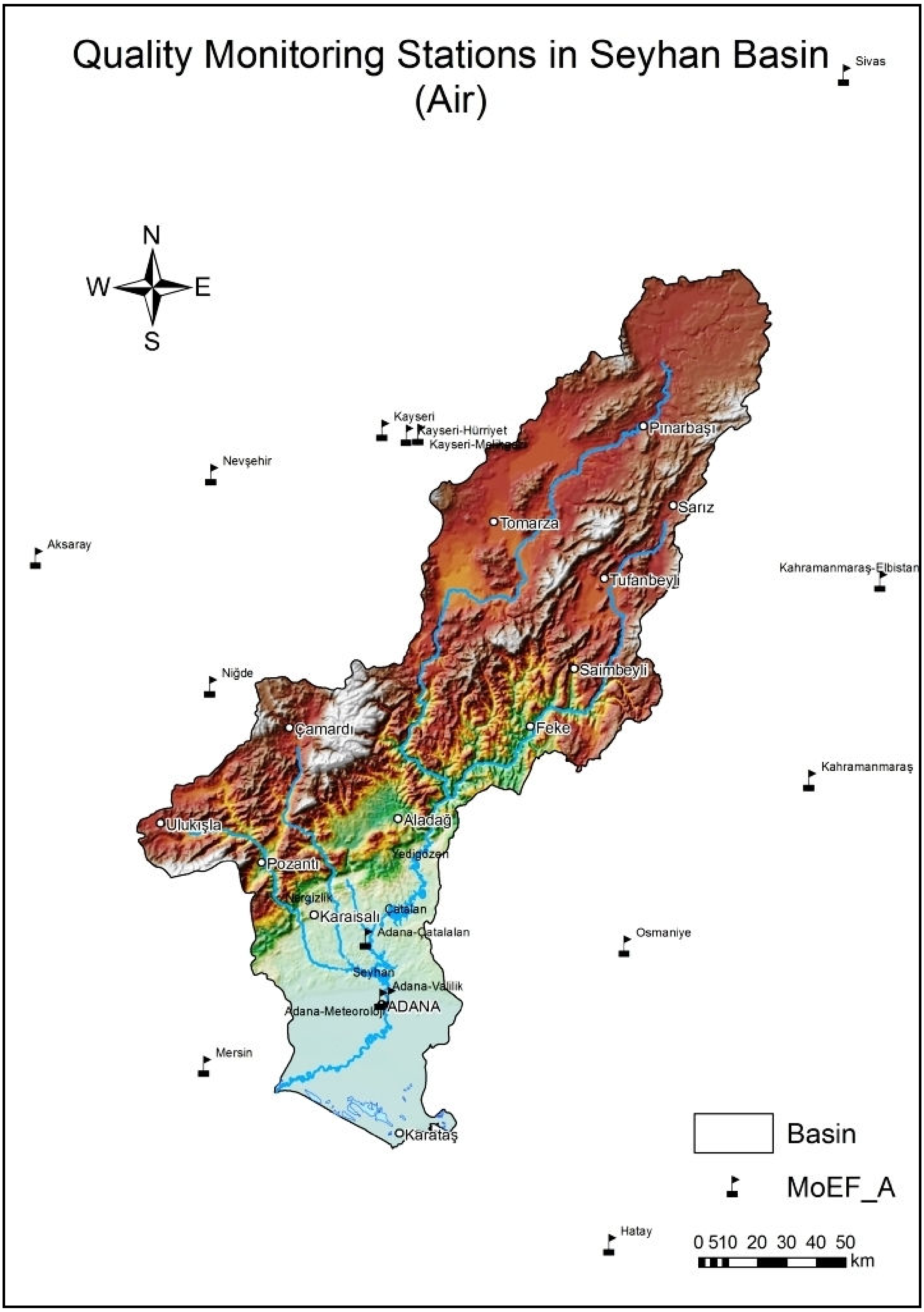

Figure 3.5. Air quality monitoring stations

3.6. INDEXING METHODS

The purpose of an index is not to describe separately a pollutant's concentration or the changes in a certain parameter. To synthesize a complex reality in a single number is the biggest challenge in the development of an EQI or an EPI, since it is directly affected by a large number of environmental variables. (Lermontov *et al*, 2009). In this study, water quality and air quality indices are developed by using the data obtained from DSI and MoEF, respectively. Afterwards, environmental quality index is developed for the common time period which both water and air quality data are present.

The development process of an EQI or EPI can be generalized in four steps:

- Concerned environmental quality variables and standards are selected.
- Environmental quality variables are weighted according to their relative importance to overall quality.
- Different units and dimensions of environmental quality variables are transformed to a common scale (sub-indices developed).
- Water, air, and environmental quality indices are formulated and developed (sub-indices are aggregated to produce an overall index) (Boyacıoğlu, 2007).

Formulation of aggregation methods is crucial in the field of environmental index development since these methods affect the quality of the results (Kumar and Alappat, 2004). In UNDESA (2000) aggregation is defined as "the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual component". Aggregation functions usually consist of any of the following three forms (Ott, 1978; Kumar and Alappat, 2004), which are additive form (summation function), multiplicative form (multiplication function), and maximum or minimum operator form. Kumar and Alappat (2004) reported that most of the air pollution indices given in literature use the additive form of aggregation function or the maximum operator form aggregation function, and independent of their functional forms, water quality indices use all three forms of aggregation functions.

The following aspects are considered for selection of the appropriate aggregation method. An index can be an increasing scale index or a decreasing scale index. In the case of an increasing scale index, environmental pollution index, higher values indicate worse state than lower values. In the decreasing scale indices, environmental quality index, higher values indicate better state than lower ones (Kumar and Alappat, 2004):

Jollands et al. (2003) reported that when competing aggregation functions produce similar results with respect to overestimation and underestimation, the most appropriate aggregation function will be the one which is mathematically simple. Hammond and Adriaanse (1995) mentioned that "an aggregation function is successful if all assumptions and sources of data are identified, the methodology is transparent and publicly reported, and an index can be readily disaggregated into the separate components with no information lost". Moreover, the aggregation function selected for any index shall also meet the following criteria (Ott, 1978; Kumar and Alappat, 2004):

- Responsive to changes in any of the variables throughout its range,
- Should reflect the true quality,
- As all variables included in the index are not equal contributors to environment pollution it shall consider weighting factors,
- Be relatively easy to use.

In this study, taking mentioned criteria into account it is decided to use "Weighted arithmetic mean function (weighted linear sum aggregation function)" as aggregation function for both of WPI and API; since it is one of the widely used function and selected as most appropriate aggregation function in a river system. Also, similar method is used by NSF for determination of EPI, and by modified EPA for calculation of API.

3.6.1. Water Pollution Index

A WPI is developed for Seyhan Basin. Data gathered from four monitoring stations (1801-Eğner, 1804-Taşköprü, 1805-Hacılı, 1816-Nergizlik) of DSI during 2004–2008 are analyzed and a WPI is developed. For development of WPI, it was not possible to use other water quality monitoring stations since either they do not have actual data (data of Şekerpınarı belongs to 1991 and Göktaş's 1988 and 1989) or the parameters are not sufficient to calculate WPI (most of the parameters analyzed by EIE are the ions that are not used in selected WQI calculation method).

In this study, it is decided that to use "Weighted arithmetic mean function" as aggregation function for WPI, since this aggregation method is reported as widely used aggregation function (Sing et al., 2002) and also it is the selected method by NSF. This aggregation function can be represented as

$$WPI = \frac{\sum_{i=1}^{n} w_i q_i}{\sum_{i=1}^{n} w_i} \qquad (3.1)$$

where *WPI*: weighted arithmetic mean water pollution index; w_i: weighting factor for the i^{th} variable; q_i: subindex value of the i^{th} pollutant variable; and n: number of pollutant variables. Since sum of weighing factors is equal to 1, the function can be simplified as

$$WPI = \sum_{i=1}^{n} w_i q_i \qquad (3.2)$$

One of the main steps for development of an index is determination of quality parameters (pollutant variables). The parameters used for water quality index development by NSF are taken as a base for selection of water quality parameters which are used in this study. The NSF parameters are DO, fecal coliform, pH, BOD_5, nitrates, phosphates, temperature, turbidity, and total solids (Ott, 1978). While selecting the parameters, availability of parameters and standards are taken into consideration.

Ott (1978) reported that the NSF surveyed 142 people representing a wide range of positions at the local, state, and national level about 35 water quality tests for possible inclusion in an index. Nine factors were chosen and some were judged more important than others, so a weighted mean is used to combine the values.

After the selection of parameters, the next step is assignment of weights for the selected pollutant variables. The weights of selected parameters are assigned according to the weights used by NSF which are given in Table 3.6 (Ott, 1978):

Table 3.6. Weights of pollutant variables used by NSF (Ott, 1978)

#	**Pollutant Variables**	**Weights**
1	Dissolved Oxygen	0.17
2	Fecal Coliform	0.15
3	pH	0.12
4	BOD_5	0.10
5	Nitrates	0.10
6	Phosphates	0.10
7	Temperature	0.10
8	Turbidity	0.08
9	Total Solids	0.08
Total	***9 variables***	***1.00***

If any of the parameters mentioned by NSF (Table 3.6.) is not used for index development in this study, the weights of the unused parameters is distributed equally to the weights of used ones in order to obtain a sum of 1.

In NSF water quality index the sub-index values are extracted from the quality graphics elaborated for each parameter. The sub-index graphics (Ott, 1978; Wilkes University, 2010) are given in Figure 3.6 (a to i)

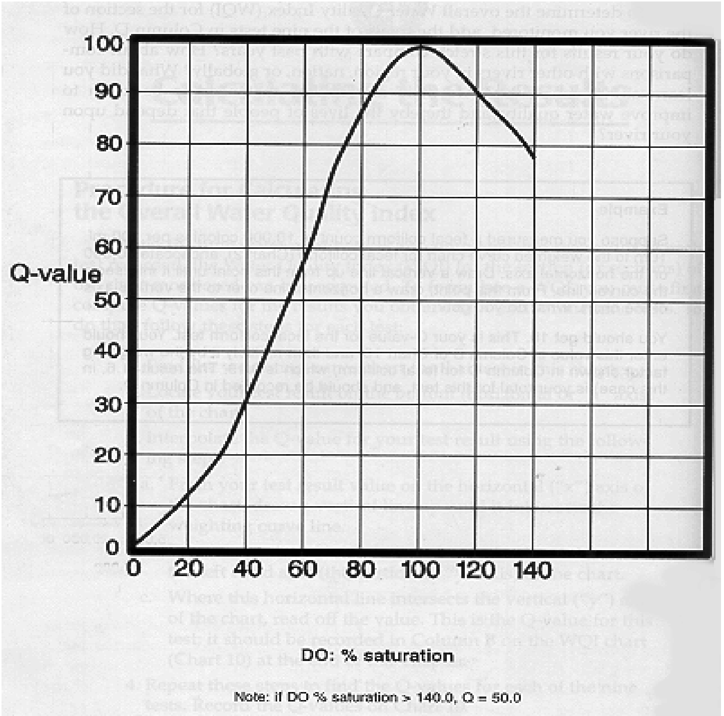

Figure 3.6.a. Sub-index graphic for dissolved oxygen (Ott, 1978; Wilkes University, 2010)

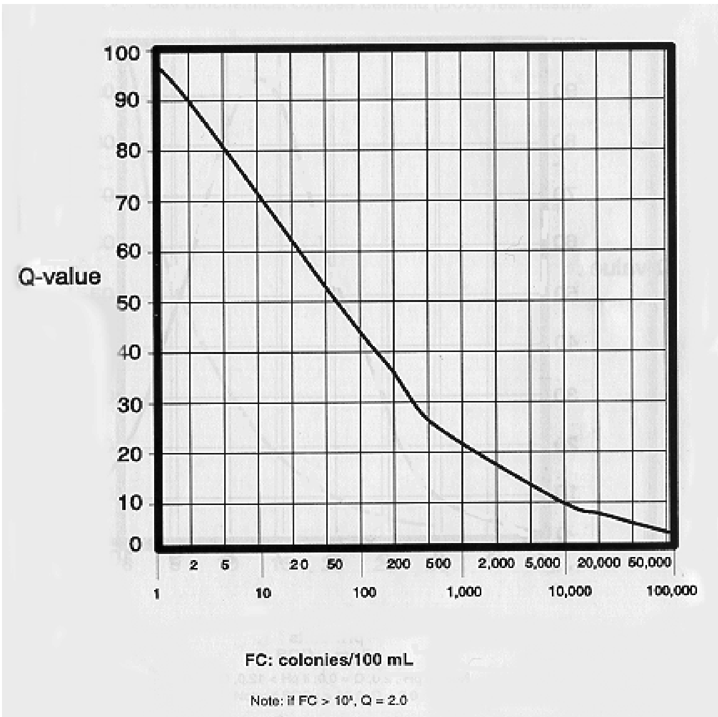

Figure 3.6.b. Sub-index graphic for fecal coliform (Ott, 1978; Wilkes University, 2010)

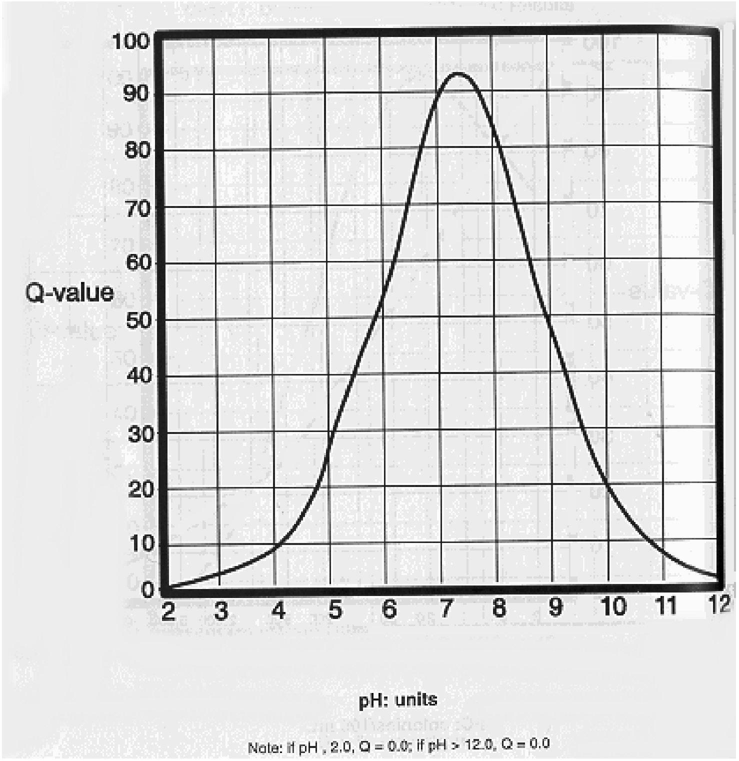

Figure 3.6.c. Sub-index graphic for pH (Ott, 1978; Wilkes University, 2010)

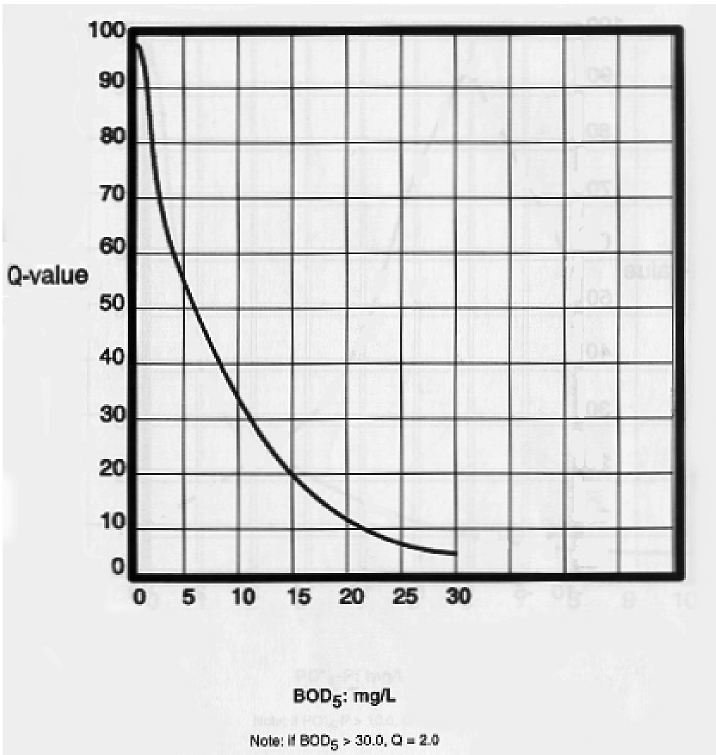

Figure 3.6.d Sub-index graphic for biochemical oxygen demand (Ott, 1978; Wilkes University, 2010)

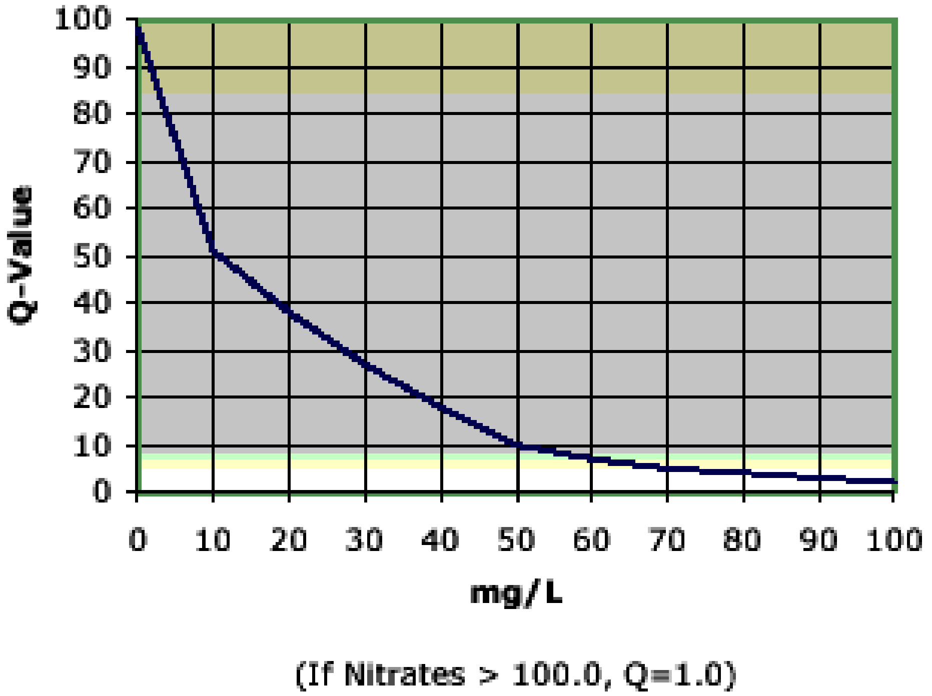

Figure 3.6.e. Sub-index graphic for nitrates (Ott, 1978; Wilkes University, 2010)

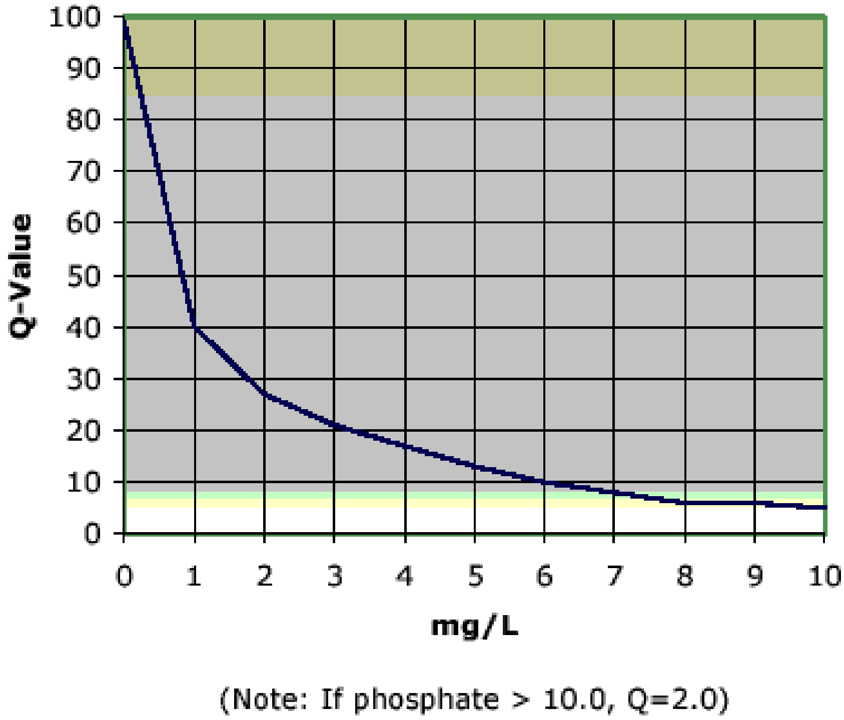

Figure 3.6.f. Sub-index graphic for total phosphates (Ott, 1978; Wilkes University, 2010)

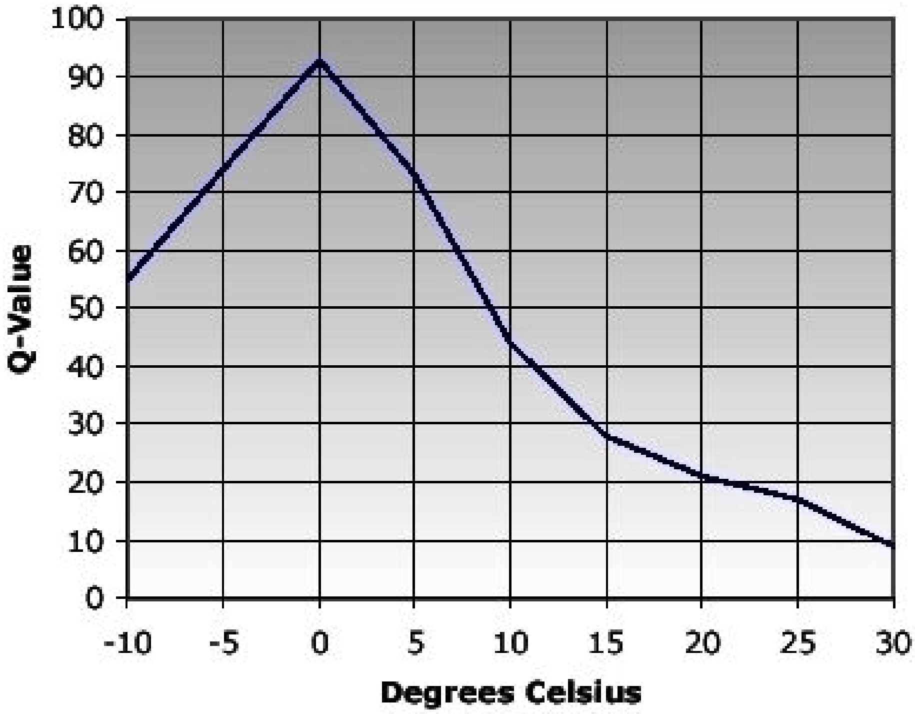

Figure 3.6.g. Sub-index graphic for temperature (Ott, 1978; Wilkes University, 2010)

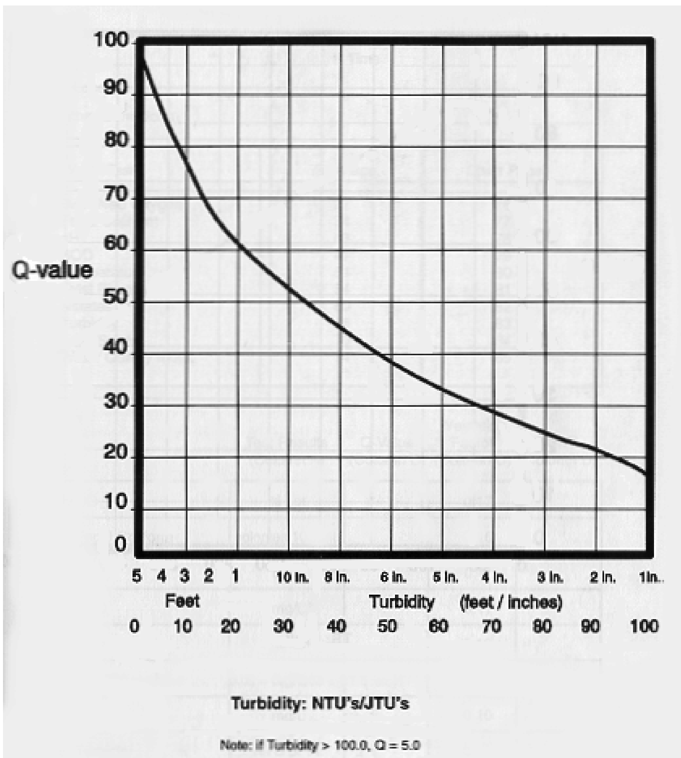

Figure 3.6.h. Sub-index graphic for turbidity (Ott, 1978; Wilkes University, 2010)

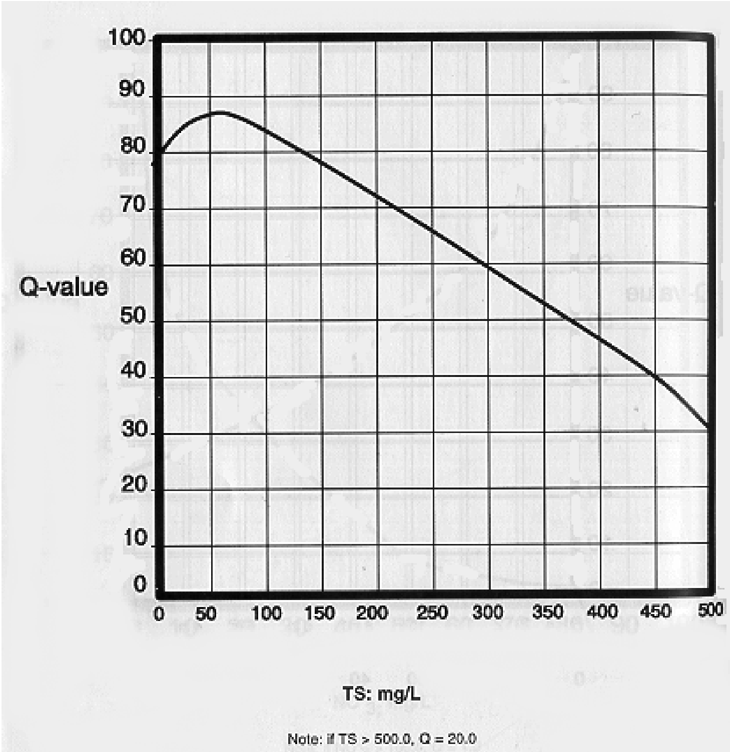

Figure 3.6.i. Sub-index graphic for total solids (Ott, 1978; Wilkes University, 2010)

As seen in Figure 3.6.a, dissolved oxygen value is given in percent, but the values obtained from DSI are in concentration. So, in order to interpret sub-index for DO, sub-index evaluation for concentration given by Pesce and Wunderlin (2000) is used, which is given in Table 3.7.

Table 3.7. Sub-index values for dissolved oxygen concentration (Pesce and Wunderlin, 2000)

Range	**Sub-index, q**
DO≤1	0
2≥DO>1	10
3≥DO>2	20
3.5≥DO>3	30
4≥DO>3.5	40
5≥DO>4	50
6≥DO>5	60
6.5≥DO>6	70
7≥DO>6.5	80
7.5≥DO>7	90
DO≥7.5	100

In this study, pollution indices are developed annually, but the values gathered from monitoring stations are seasonal. So, in order to obtain annual concentrations for pollutant variables arithmetic mean of seasonal concentrations is taken as the annual concentration. Finally, the classification of the indices are done also by according to the NSF index classification (Ott, 1978; Terrado et al., 2009) given in Table 3.8.

Table 3.8. NSF water quality index classification (Ott, 1978; Terrado et al., 2009)

Range of Index	Class
100-91	Excellent
90-71	Good
70-51	Regular
50-26	Bad
25-0	Very bad

As a result, the selected aggregation function, weighted arithmetic mean aggregation function given in Equation 3.2 is used for overall water pollution index for the time period of 2004-2008; and annual indices are classified for water quality according to Table 3.8

3.6.2. Air Pollution Index

An air pollution index (API) is developed for Seyhan Basin. Data gathered from sixteen air monitoring stations (Table 3.4) of MoEF during 2007–2009 are analyzed and an API is developed. As in water pollution index development, one of the main steps for development of an air pollution index is determination of quality parameters (pollutant variables) which will be used for index calculation. In literature a variety of air quality parameters are used. The most used ones are sulfur dioxide (SO_2), particulate matter (PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3) (EPA, 1999). In this study, parameters are selected according to availability of data at the air quality monitoring stations for the selected time period. According to this constraint, SO_2 and PM_{10} are the selected values.

After the selection of parameters, the next step is the assignment of weights for the selected pollutant variables. The weights of selected parameters, SO_2 and PM_{10}, are assigned according to Sharma et al., 2008. Sharma et al. (2008) assigns weights for different air quality parameters including SO_2 and PM_{10}; and reports weighting of *0.105*/1.00 and 0.*165*/1.00 for SO_2 and PM_{10}, respectively. By using these data, weights of selected parameters are recalculated in order to complete the total weights of selected two parameters to 1.00. The calculations are as follows:

$$w_{SO_2} = \frac{0.105}{(0.105 + 0.165)} = \frac{0.105}{0.270} = 0.389 \qquad (3.3.a)$$

$$w_{PM_{10}} = \frac{0.165}{(0.105 + 0.165)} = \frac{0.165}{0.270} = 0.611 \qquad (3.3.b)$$

As seen in Equations 3.3.a and 3.3.b, relative weights of SO_2 and PM_{10} are calculated as *0.389* and *0.611*, respectively.

The sub-index value, q_i, is calculated by taking air quality index proposed by EPA. EPA defined five main common pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}) and sulphur dioxide (SO_2). Pollutants concentrations are converted into a numerical index (AQI) which assumes values in the range 0–500. The overall range is subdivided into six ranges to which six categories of air quality (Murena, 2004; EPA, 2010/a). The subclasses and their breakpoints for AQI of EPA for selected parameters are given in Table 3.9.

Table 3.9. Breakpoints for the AQI of EPA (Murena, 2004; EPA, 2010/a)

Levels of Health Concern	**AQI**	**SO_2 (µg/m^3)**	**PM_{10} (µg/m^3)**
Hazardous	500-301	2673-1608	563-396
Very unhealthy	300-201	1607-810	395-331
Unhealthy	200-151	809-597	330-238
Unhealthy for sensitive groups	150-101	596-384	237-144
Moderate	100-51	383-91	143-51
Good	50-0	90-0	50-0

Bishoi et al. (2009) reported that the AQI measures daily pollution index of the pollutants for which EPA has established NAAQS. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. Murena (2004) has modified EPA's AQI by taking limit and target values established by European Community as reference scale. With respect to EPA's AQI five categories are defined instead of six, which are "*good quality, low pollution, moderate pollution, unhealthy for sensitive groups,* and *unhealthy*". The reference scale of the air pollution index with the corresponding pollution categories is reported for each pollutant in Table 3.10. The reference scale can assume values in the range 0-100.

Table 3.10. Breakpoints of air pollution index (Murena, 2004)

Pollution Category	**AQI**	**SO_2 (μg/m^3)**	**PM_{10} (μg/m^3)**
Unhealthy	100-86	1000-501	500-239
Unhealthy for sensitive groups	85-71	500-251	238-145
Moderate pollution	70-51	250-126	144-51
Low pollution	50-26	125-21	50-41
Good quality	25-0	20-0	40-0

Since the Turkish Regulation on Assessment and Management of Air Pollution is harmonized with EU's Council Directive on Ambient Air Quality Assessment and Management, the same breakpoints are taken to evaluate API for Seyhan Basin. In order to determine sub-index values for the different concentration linear interpolation between the ranges are carried. In this study, pollution indices are developed in annual basis. Since air quality data obtained from monitoring stations are daily, annual averages are calculated for SO_2 and PM_{10}.

As a result, the selected aggregation function, weighted arithmetic mean function, is used for overall air pollution index by using Equation 3.2 for the time period of 2007-2009; and indices developed annually for air. Finally, developed indices are evaluated according to their pollution category.

3.6.3. Environmental Pollution Index

Following development of water and air pollution indices, an environmental pollution index (EPI) is developed for Seyhan Basin. As mentioned previous chapters, WPI is developed for the years 2004-2008 and API for the years 2007-2009, because of the data availability. Therefore, only for 2008, it was possible to calculate both WPI and API. Since both are required for calculations, EPI is developed only for the year 2008.

A critical point in EPI development in this study is to estimate the air pollutant values at water quality monitoring stations since the locations of water and air quality monitoring stations are different. In order to estimate the concentration of air pollutant variables at water quality monitoring stations, statistical methods under ArcGIS 9.3 software are used.

Visiting every location in a study area to measure the height, magnitude, or concentration of a phenomenon is usually difficult or expensive. Instead, phenomenon at strategically dispersed sample locations can be measured, and predicted values can be assigned to all other locations by using the measured values. Input values (points) can be either randomly or regularly spaced or based on a sampling scheme. Surface interpolation functions create a continuous (or prediction) surface from sampled point values. The continuous surface representation of a raster dataset represents height (eg. elevation), magnitude (eg. noise), or concentration (e.g. pollution) (ESRI, 2010/e). In this study, raster data sets representing pollutant concentration are used for air quality parameters.

Surface interpolation functions make predictions from measured phenomena for all locations in a raster dataset whether or not a measurement has been taken at the location. There is a variety of ways to derive a prediction for each location; each method is referred to as a model. With each model, there are different assumptions made of the data, and certain models are more applicable for specific data. Each model produces predictions using different calculations (ESRI, 2010/e). The models can be grouped as "deterministic interpolation methods" such as "inverse distance weighted (IDW)" and "spline" methods and "geostatistical methods" such as "kriging".

Deterministic interpolation methods assign values to locations based on the surrounding measured values and on specified mathematical formulas that determine the smoothness of the resulting surface. Geostatistical methods, which are based on statistical models, include autocorrelation (ESRI, 2010/e).

IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable. IDW relies mainly on the inverse of the distance raised to a power (ESRI, 2010/f).

Another interpolation method is the spline method that estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. In this method, "the sample points are extruded to the height of their magnitude; spline bends a sheet of rubber that passes through the input points while minimizing the total curvature of the surface. It fits a mathematical function to a specified number of nearest input points while passing through the sample points" (ESRI, 2010/g).

The third interpolation method is the kriging method which is a geostatistical method. These methods based on statistical models that include autocorrelation, and kriging assumes that the distance or direction between sample points reflects a spatial correlation which can be used to explain variation in the surface (ESRI, 2010/h).

Kriging and inverse distance weighted methods are similar that they weight the surrounding measured values to derive a prediction for the unmeasured locations. The general formula for both of the interpolation methods is a weighted sum of data (ESRI, 2010/h).

$$\hat{Z}(s_o) = \sum_{i=1}^{N} \lambda_i Z(s_i) \tag{3.4}$$

where $Z(s_i)$ = the measured value at the i^{th} location; λ_i = an unknown weight for the measured value at the i^{th} location; s_o = the prediction location; and N = the number of measured values.

In this study, all three interpolation methods (inverse distance weighted, spline, and kriging) are evaluated for the data of air quality monitoring stations for the year 2008. Fifteen of sixteen stations have SO_2 and PM_{10} measurements for the selected year. However, Adana-Doğankent station has not particulate matter measurement for that year. In this context, aforementioned station is not taken for evaluation of interpolation methods. The 2008 data of the stations are given in Table 3.11.

Table 3.11. Values of air pollutants variables measured at air quality monitoring stations for the year 2008

Station	**SO_2 (µg/m^3)**	**PM_{10} (µg/m^3)**
Adana-Çatalalan	0.47	42.20
Adana-Doğankent	*14.25*	---
Adana-Meteoroloji	4.83	72.54
Adana-Valilik	6.27	113.27
Aksaray	53.13	60.10
Hatay	11.09	98.00
Kahramanmaraş	37.73	103.89
Kahramanmaraş-Elbistan	23.04	136.03
Kayseri	8.21	94.76
Kayseri-Hürriyet	35.80	95.20
Kayseri-Melikgazi	13.56	69.33
Mersin	9.69	94.15
Nevşehir	45.83	68.82
Niğde	14.70	62.39
Osmaniye	5.34	93.74
Sivas	113.27	89.79

The values of air pollutants variables measured at air quality monitoring stations for the year 2008 are used to produce air quality data for water quality monitoring stations via ArcGIS 9.3 software.

In this study, by using the 'Spatial Analyst/Interpolate to Raster' functions, rasters showing the interpolated data for the entire area are produced with different interpolation methods. Afterwards, with the 'Spatial Analyst/Surface Analysis/Contour' function, exact values of pollutant variables at desired locations are determined. The produced results of different interpolation methods are given in Appendix G. These results are compared with the measured variables and distribution of produced values. The results obtained by inverse distance weighted method showed the right values at air quality monitoring stations and it is concluded that inverse distance weighted method is the most suitable interpolation function in our case. Afterwards, by using inverse distance weighted method the measured values of air pollutant variables interpolated to the location where water quality monitoring stations are. Later API values are calculated at the locations where water quality observation stations are located.

The last step is the development of an EPI. As mentioned before, in this development weights of WPI and API are taken as equal (0.5 for each). The critical point here is the water pollution index has a decreasing scale index, thereby a lower index value indicates a poorer water quality, whereas air pollution index has an increasing scale index. Hence, one of the indices needs to be converted to an increasing or decreasing scale. However, even the scales are converted, problem still exist since the ranges of different classes are different. So, the problem when determining the environmental pollution index is the aggregation of the two indices, for water and air. In this case aggregation methods based on linguistic interpretation and again on weighted arithmetic mean function are used.

The linguistic interpretation is based on the classification of the indices. The classification of water and air pollution indices is summarized in Table 3.12.

Table 3.12. Classification of water and air quality indices

Classification of Water Quality Indices				
100-91 Excellent	90-71 Good	70-51 Regular	50-26 Bad	25-0 Very Bad
Classification of Air Quality Indices				
0-25 Good quality	26-50 Low pollution	51-70 Moderate pollution	71-85 Unhealthy for sensitive groups	86-100 Unhealthy

According to the present water and air quality indices, a matrix including both of the indices is developed as in Figure 3.7. In this figure, the common ranges which have the same classification are shown, and renamed. That is, EQI is defined as linguistic variables with five linguistic terms *excellent, good, moderate, bad*, and *very bad*.

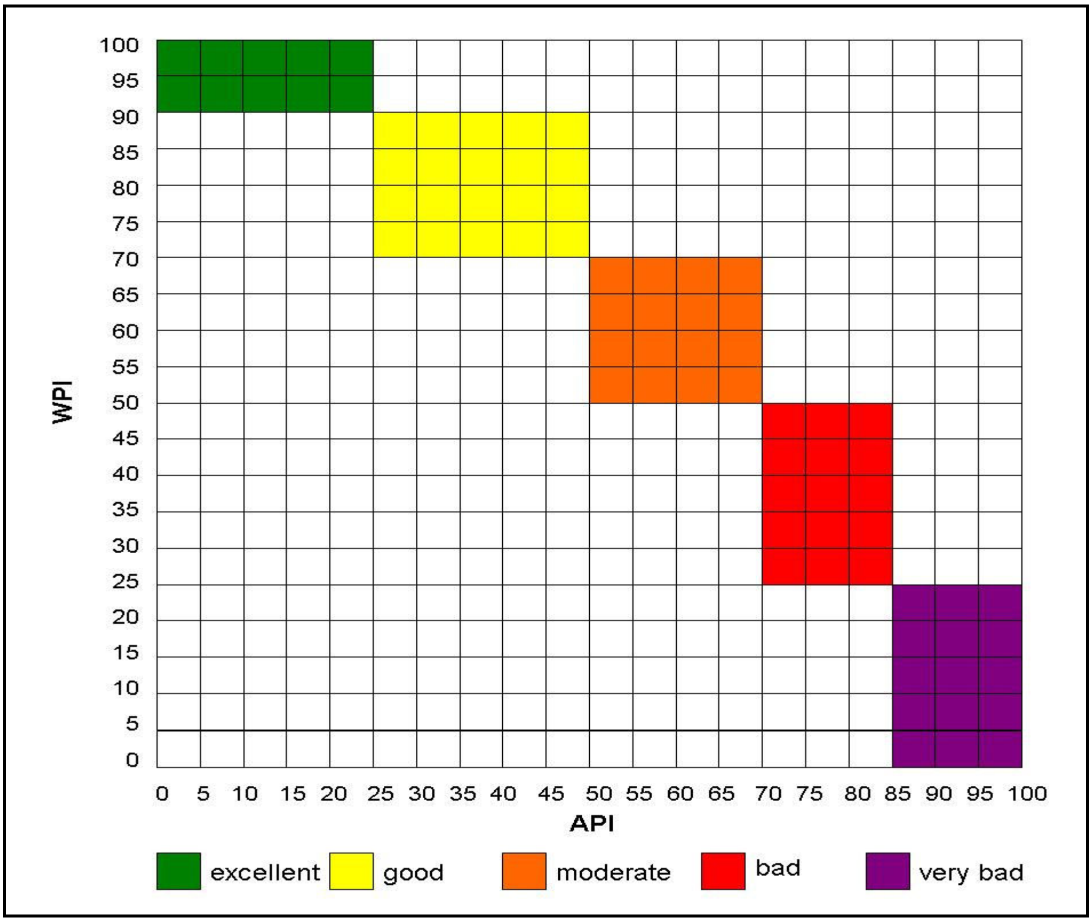

Figure 3.7. Common index ranges which have the same classification

In Figure 3.7, the common ranges which have the same classification are shown. For example, WPI is excellent in the range of 90-100, and API is in excellent quality in the range of 0-25. So, the common range shown in green color shows excellent EPI. In addition to the common ranges, it is required to enlarge this classification to include other index values (shown as white boxes in Figure 3.7). So, the matrix is divided in to classes as shown in Figure 3.8.

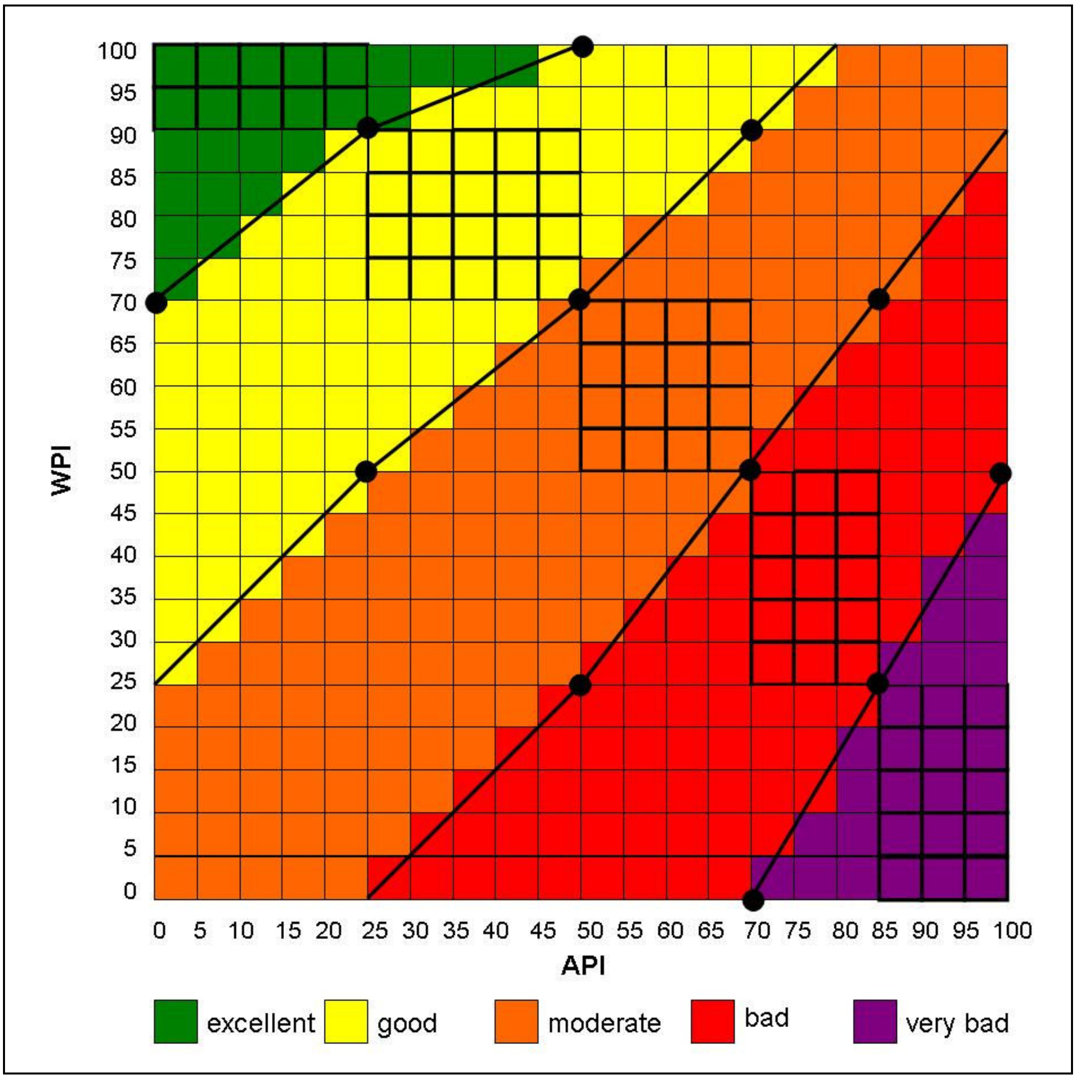

Figure 3.8. Classified common index ranges which have the same classification

As shown in Figure 3.8, the matrix is divided into five classes with lines passing through the breakpoints of the WPI and API and intersections of the classes. For example; if we say x to API, and y to WPI, the line passing from the points (0,70), (25,90), and (50,100) forms the breakpoint for the classes excellent and good. Note that, the points that the lines passing through are the breakpoints of WPI and API. If these mentioned lines are redrawn in order to pass from all of the breakpoints, it would result in a matrix as shown in Figure 3.9.

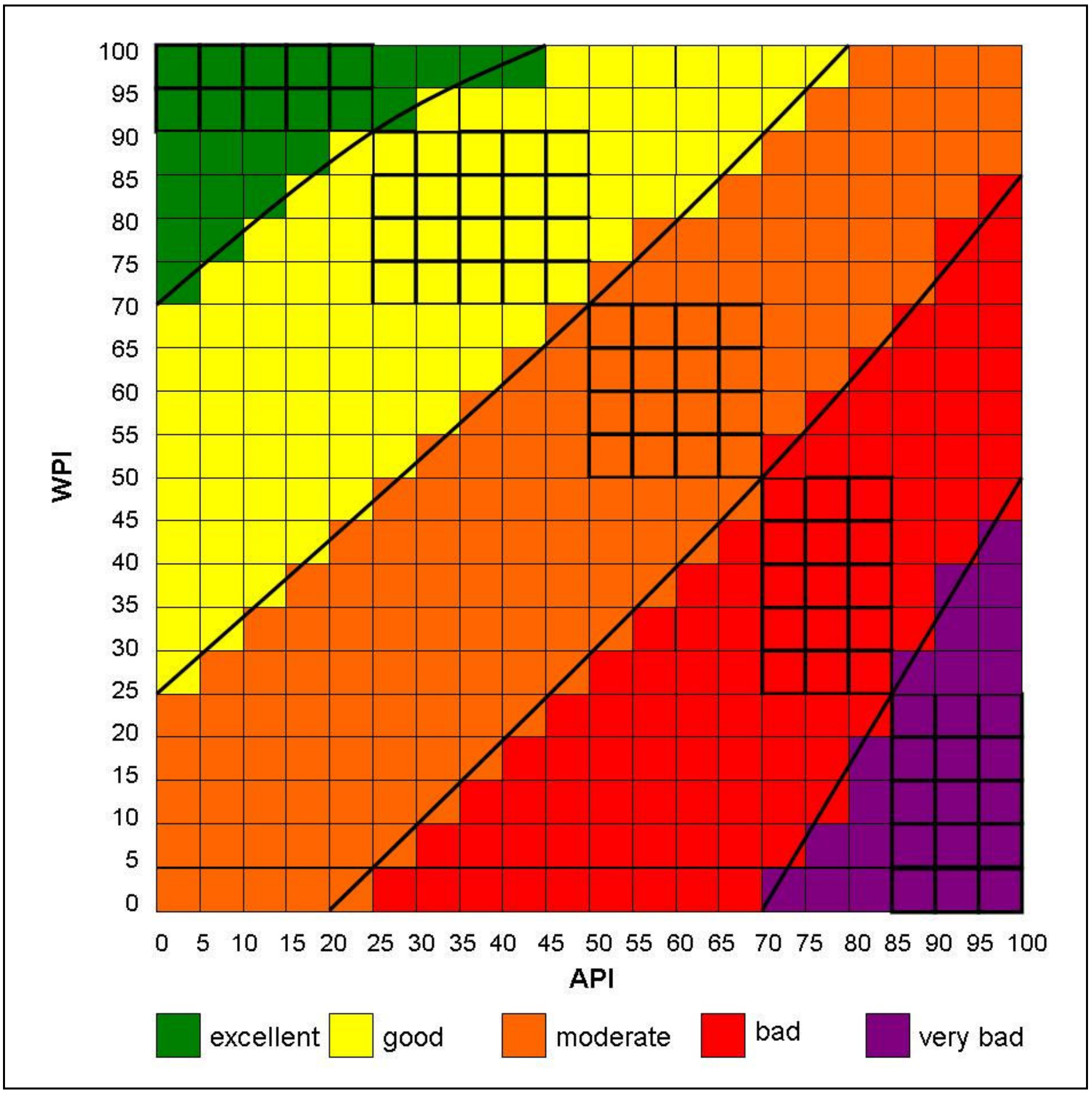

Figure 3.9. EPI determination from indices

When the lines are passed through all of the breakpoints and having the lines smother, the obtained result is given Figure 3.9. By using it, EPI can be determined linguistically. For instance, when a system has high API (e.g. 95) showing unhealthy situation, and high WPI (e.g. 95) showing excellent situation, then the assigned EPI will be moderate.

In addition to graphical and linguistic determination of EPI, another method based on weighted on arithmetic mean aggregation function is used for EPI development. The weighted arithmetic mean aggregation function includes weight of a variable, w_i, and sub-index value for that variable, q_i. As seen in previous sections both of the water and air quality indices are ranged into five classes and those five classes are combined for EPI as excellent, good, moderate, bad, and very bad. Here these classes are taken as a base for sub-index, and the weights of both WPI and API are taken equal, that is 0.50 for each. The assigned sub-index values for the indices are given in Table 3.13.

Table 3.13. Assigned sub-index values for WPI and API

WPI	**API**	w_i
91-100	0-25	5
71-90	26-50	4
51-70	51-70	3
26-50	71-85	2
0-25	86-100	1

After the determination of the sub-index value of any of the pollution index, the EPI is calculated by using weighted arithmetic mean function. After the calculation of EPI, it can be classified again on its value by using the same expression. The classification is given in Table 3.14. By using the calculated EPI, it can be classified as given in Table 3.14.

Table 3.14. Classification of EPI

EPI	**Classification**
$4<EPI\leq5$	Excellent
$3<EPI\leq4$	Good
$2<EPI\leq3$	Moderate
$1<EPI\leq2$	Bad
$EPI=1$	Very bad

CHAPTER 4

RESULTS

4.1. DATABASE FOR SEYHAN BASIN

One of the scopes of this study was to establish a database for the Seyhan Basin consisting of the basin delineation which is derived from DEM, flow accumulation, and CORINE land cover classification which is obtained by processing the remotely sensed images, field work, and literature information. In addition, locations of the air and water quality monitoring stations, measured concentrations at these stations were input into the database. With ArcGIS 9.3 software, firstly, the basin is delineated and flow accumulation in Seyhan River Basin is determined. Flow accumulation in the Seyhan River Basin, including Seyhan River and its tributaries, is shown in Figure 4.1 with the borders of the basin. In Figure 4.2, the elevation map is given. The protected areas, including wild life reserves, national parks, and wetlands of internationally are depicted on Figure 4.3.

As seen in Figure 4.1, flow accumulation increases as tributaries feed the main stem and the highest accumulation is observed at the south of the basin. The river flow pathways constitute a transport route for potential pollution that reach to the waterway as a result of direct discharge or via surface runoff. Therefore, if analyzed together with the land use information, pollution risk areas can be defined. Figure 4.2 indicates that south of the basin has lower elevations compared to the north of the basin. The elevations together with the soil data (i.e. type of soil) would indicate the risky areas in the basin that would be subject to surface runoff. Unfortunately, it was not possible to obtain the soil data within the study period. However, some of the information required for such as analysis is now in the database and in future the study can be extended. Protected areas are the locations sensitive to pollution. Therefore, water and air quality should be in a good state in these locations.

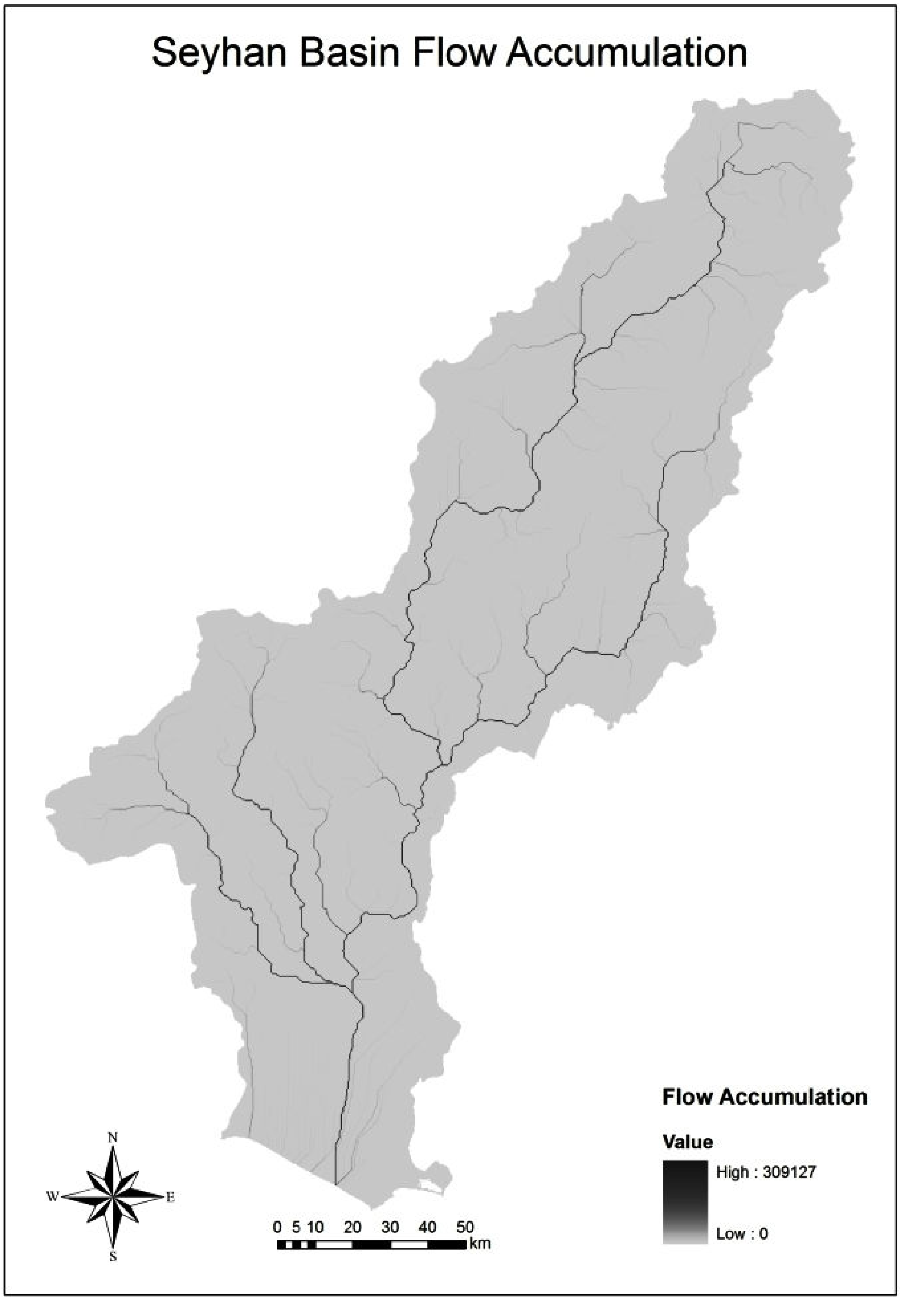

Figure 4.1. Seyhan Basin Flow Accumulation

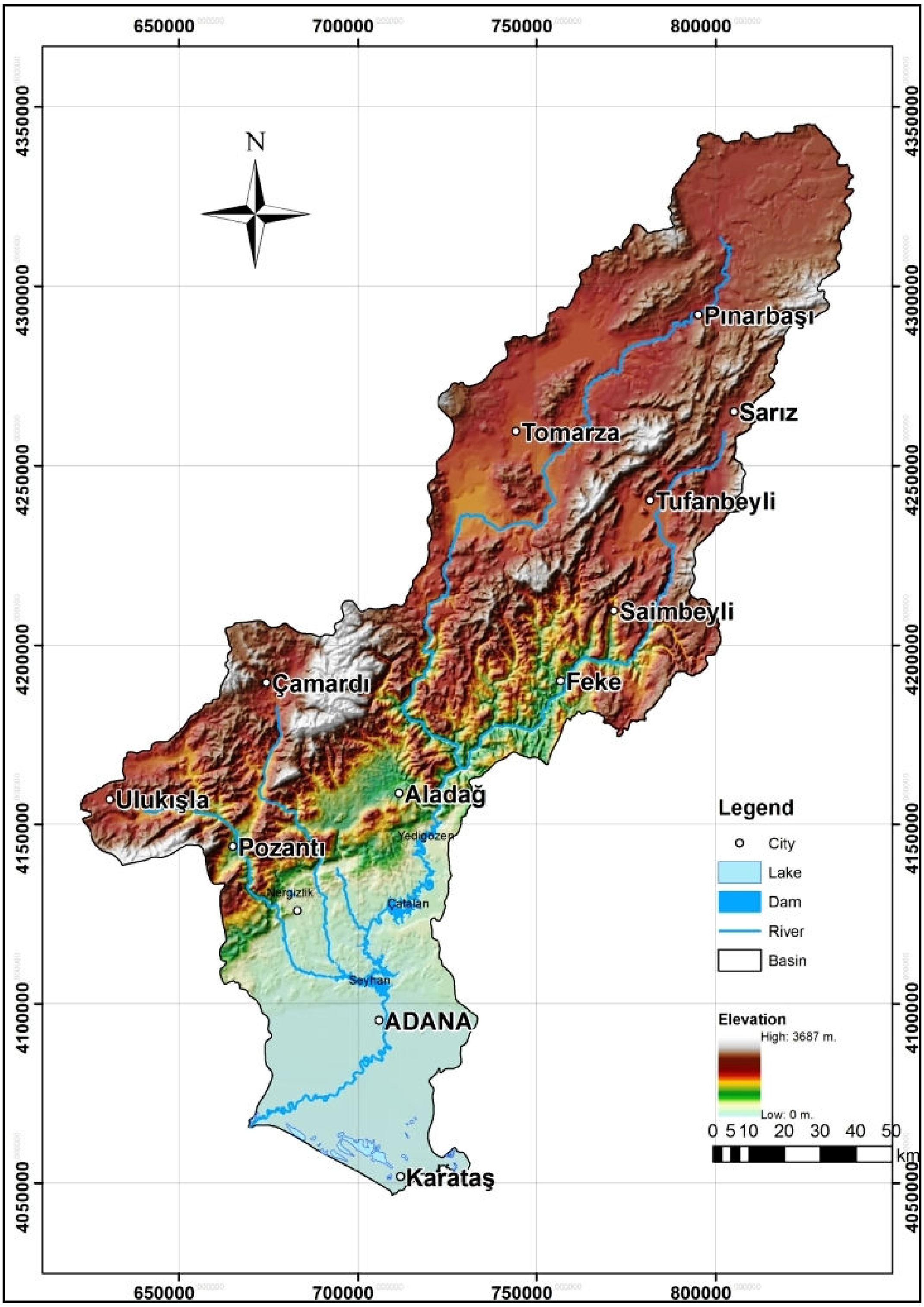

Figure 4.2. Seyhan River Basin

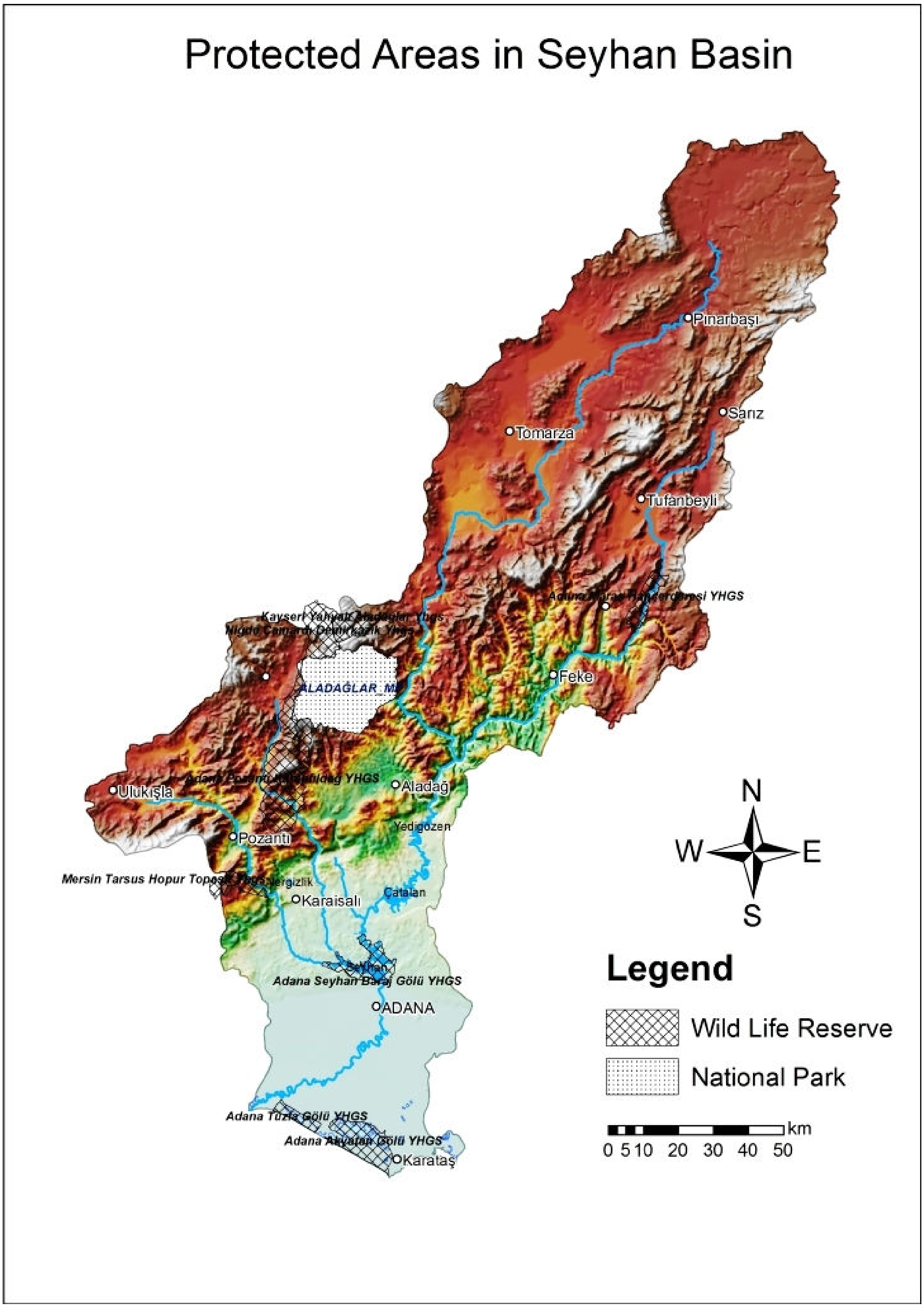

Figure 4.3. Protected Areas in Seyhan Basin

4.1.1. Land Cover

In order to map the land cover, satellite images containing the Seyhan Basin are obtained from the MoEF. In order to derive land cover of the area, land cover data from field surveys and literature are collected by random sampling of the areas. With the land cover data as reference material which describes spectral responses of known areas are generated and used to classify each pixel of the entire basin into one of the CORINE Land Cover Classification (CLCC).

In CLCC, there are five main classes and various sub-classes. The main CORINE land cover classes are

- artificial surfaces,
- agricultural areas,
- forests and semi-natural areas,
- wetlands,
- water bodies.

After classification, land cover of the basin is mapped. The land cover of Seyhan Basin, which is classified according to CLCC is shown in Figure 4.4. Moreover, maps showing the five main CORINE classes listed above are given in Figures 4.5 (a to e).

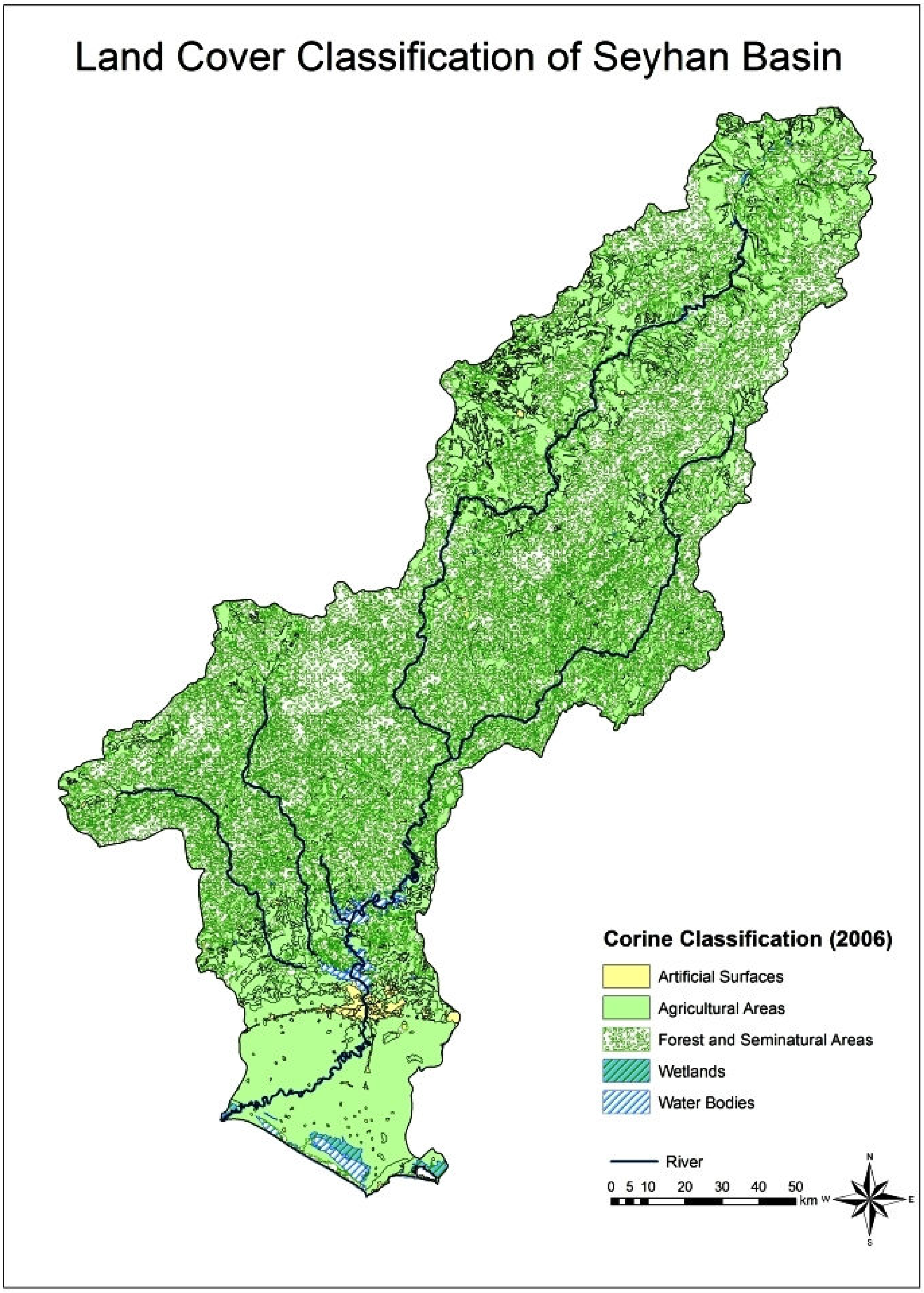

Figure 4.4. Seyhan Basin Land Cover Classification

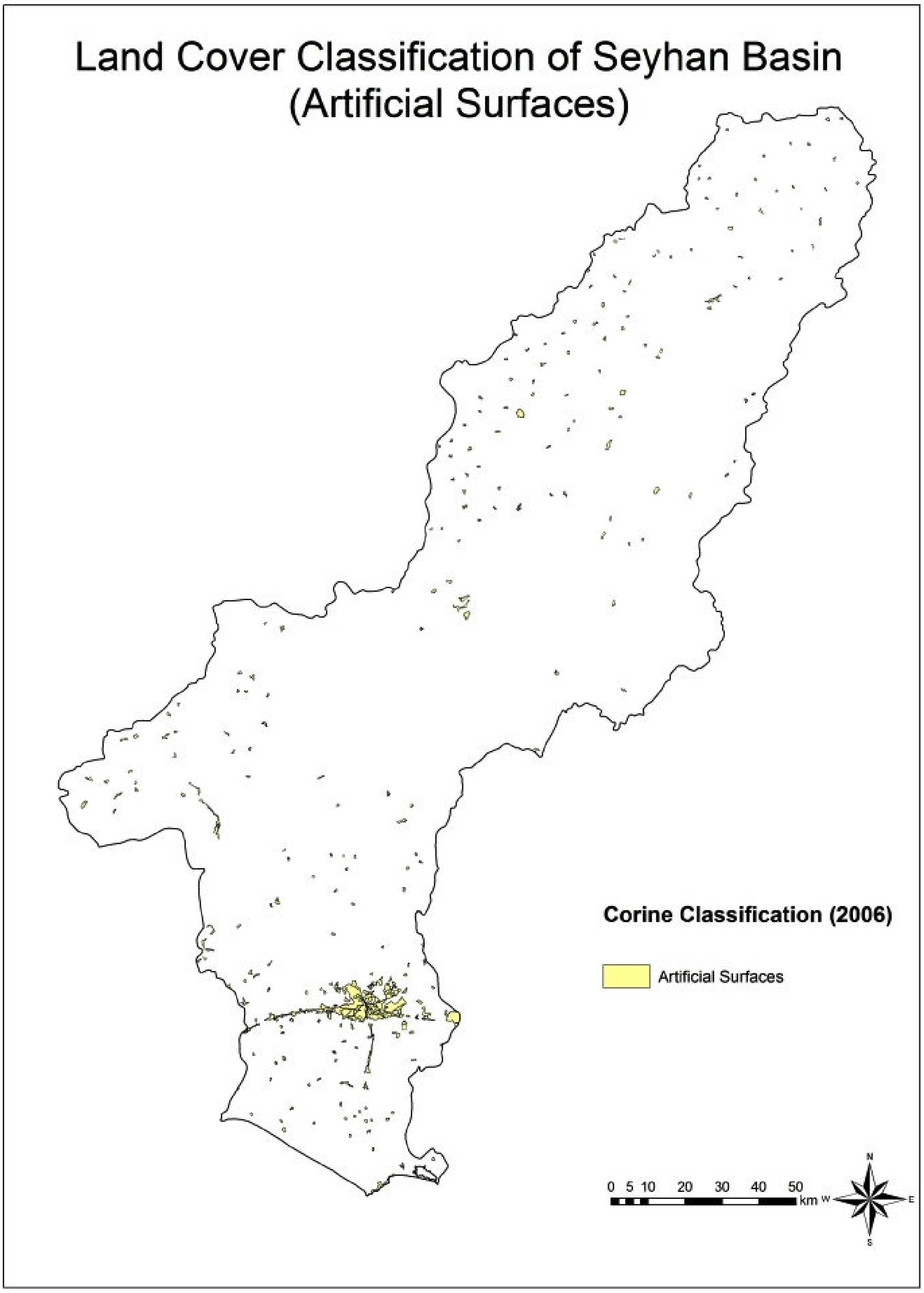

Figure 4.5.a. Seyhan Basin and Land Cover of Artificial Surfaces Class

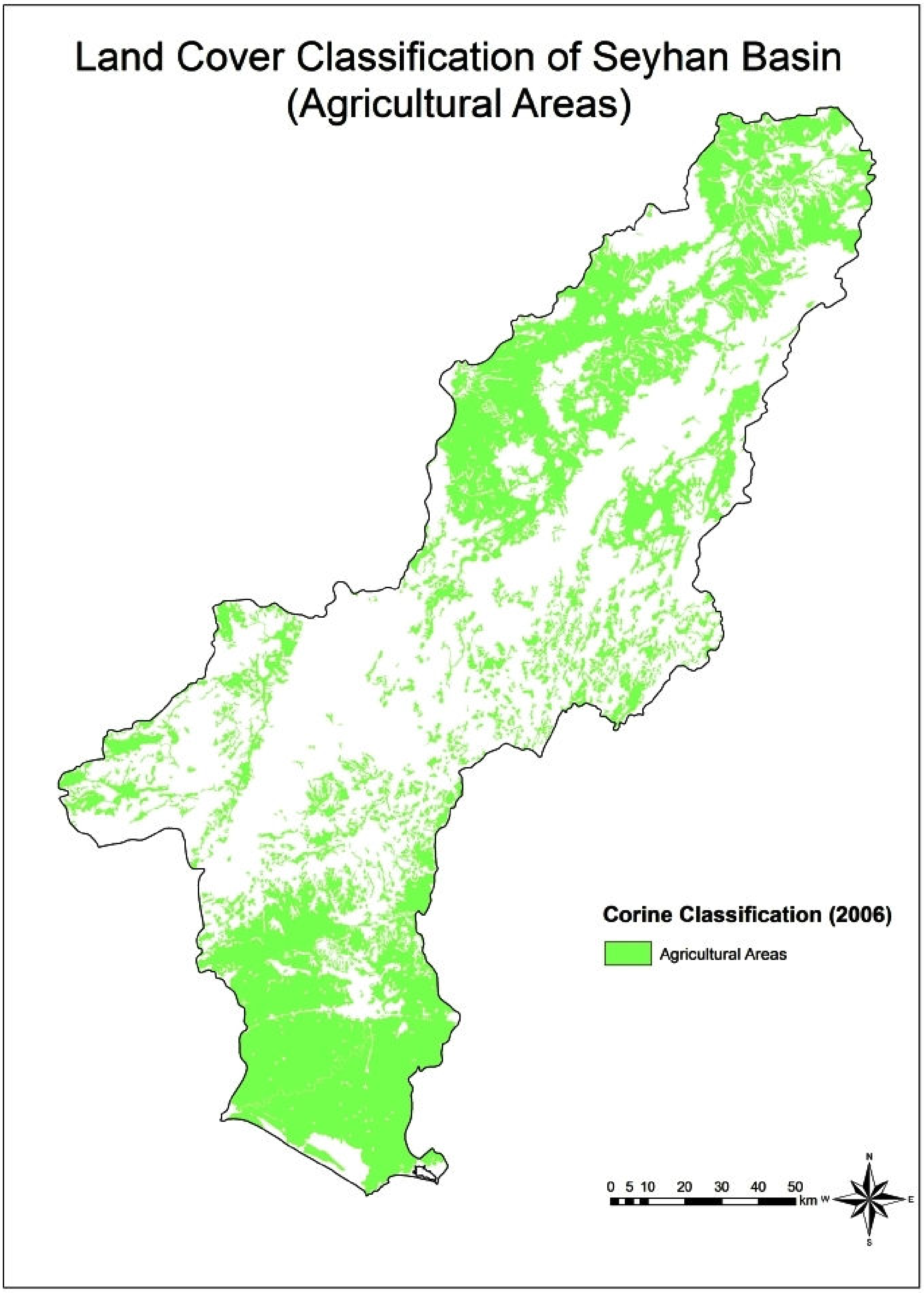

Figure 4.5.b. Seyhan Basin and Land Cover of Agricultural Areas Class

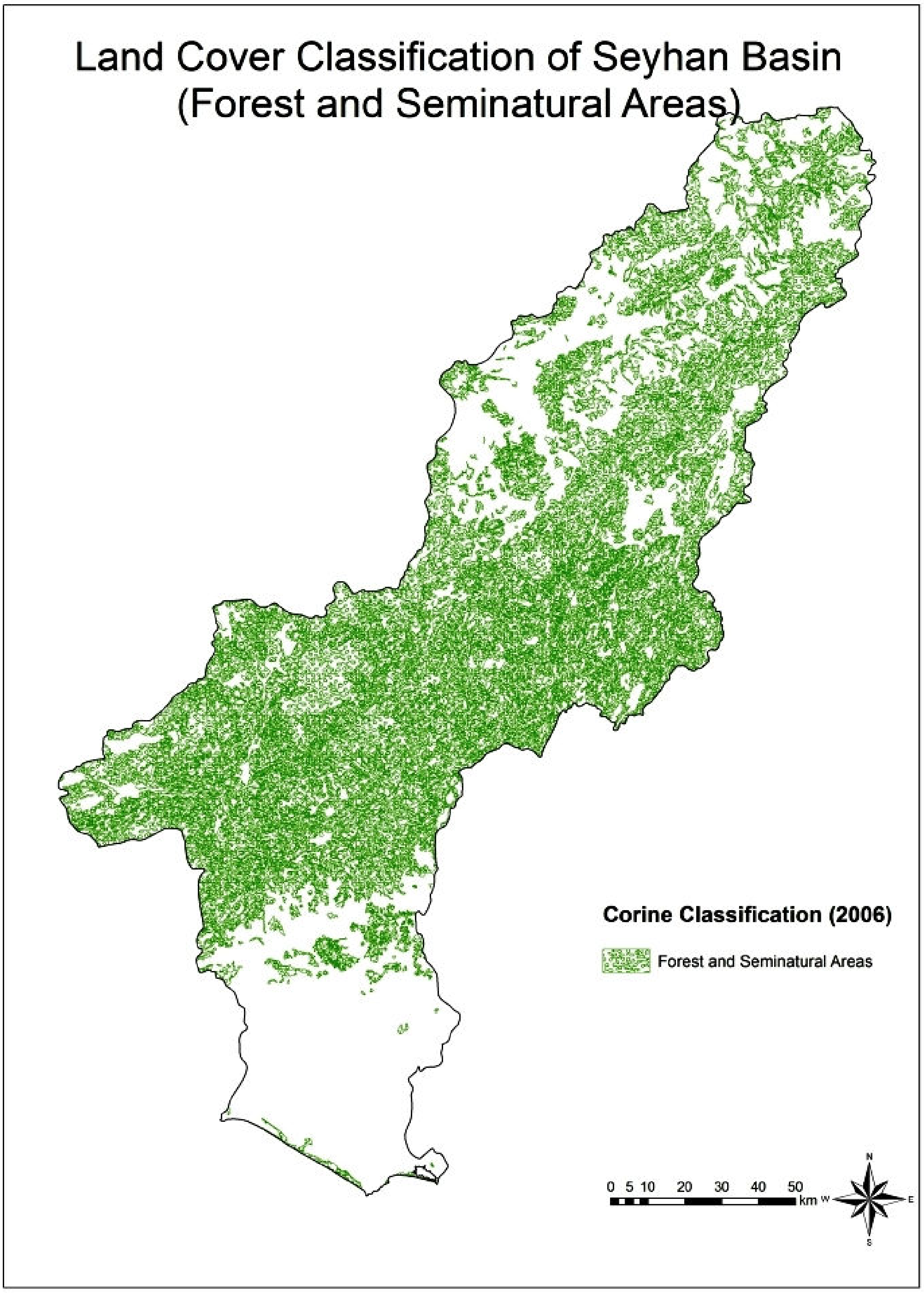

Figure 4.5.c. Seyhan Basin and Land Cover of Forests and Seminatural Areas Class

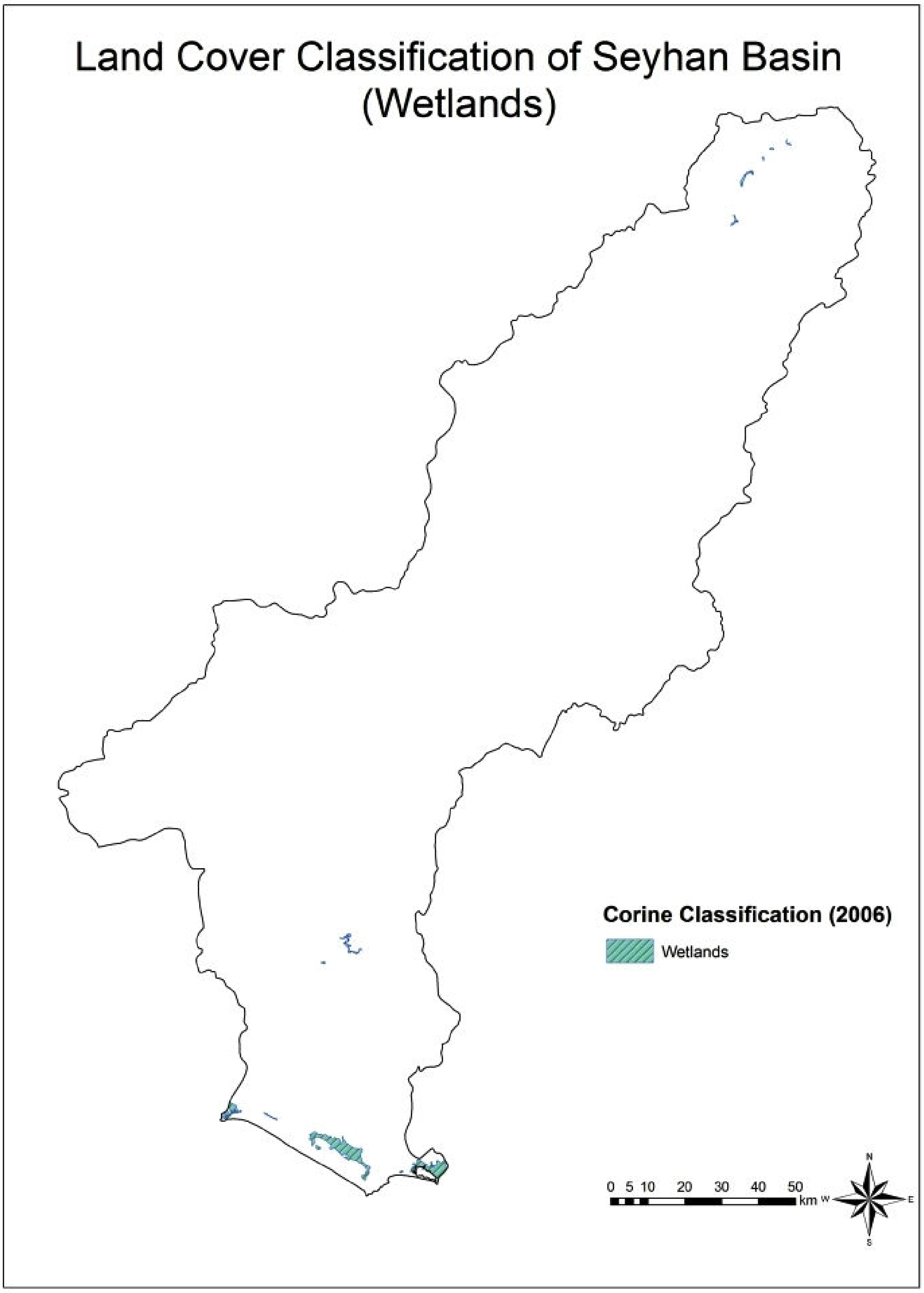

Figure 4.5.d. Seyhan Basin and Land Cover of Wetlands Class

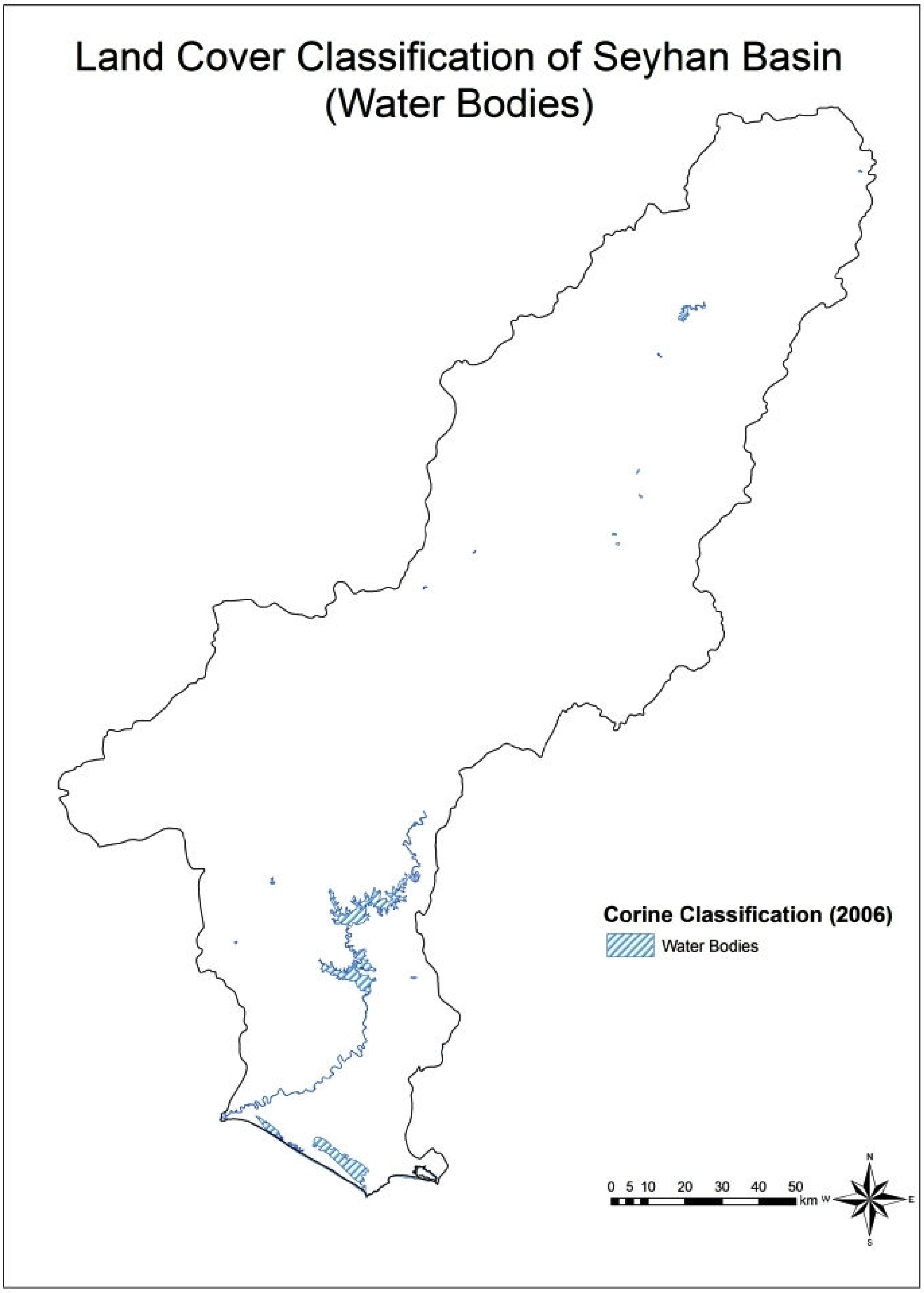

Figure 4.5.e. Seyhan Basin and Land Cover of Water Bodies Class

In Figure 4.5.a, it is seen that the denser artificial surfaces are situated around Adana and Adana-Mersin highway. In addition, the other artificial surfaces in the basin coincide with the residential areas. In Figure 4.5.b, the agricultural areas are depicted. When compared with the elevation map in Figure 4.2, it is seen that agricultural activities are conducted at locations where the slope is not steep and plain areas can be found. South of the basin has a higher percentage of land devoted to agriculture. More importantly, the flow is through the agricultural areas in the up north and south of the basin. Therefore, if precautions are not taken, especially the lower part of the basin can be subject to distributed pollution. In fact, the industrial areas are mostly found in the south of the basin. Therefore, south of the basin is under more pollution risk. The presence of forests in the northern part of the basin, as given in Figure 4.5.c, can reduce the surface runoff from the agricultural areas in the northern part. However, more data and analysis are required to come up with conclusions. In Figure 4.5.d and 4.5.e, wetlands and water bodies are depicted, respectively. It must be emphasized that these are located in the south of the basin which may be subject to more pollution loads compared to the northern section. Therefore, pollution in the south of the basin should be followed with a greater effort. It was observed that locations of the DSI sampling stations were not adequate. Use of GIS and processing of the data related with land cover, soil type, agricultural and industrial activities spatially can aid in selecting better locations for sampling points in order to define the pollution levels in the basin.

4.1.2. Meteorological Data

The monthly average values of temperature, total precipitation, and wind speed measured at selected meteorological stations for time period of 1989-2008 are given in Tables 4.1, 4.2, and 4.3, respectively. Also, they are graphically represented in Figures 4.6, 4.7, and.4.8.

Table 4.1. Monthly average temperature measured (1989-2008)

	Temperature (°C)											
Months Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tufanbeyli	-3.0	-2.1	4.1	9.3	13.3	18.4	22.4	22.9	18.0	12.3	5.3	-1.1
Gülek	4.5	5.3	8.4	12.5	17.2	21.4	24.4	24.4	21.2	16.7	10.4	6.2
Kayseri	-1.8	-0.6	5.3	10.9	15.1	19.4	23.1	22.8	17.8	12.2	5.2	0.0
Niğde	-1.1	0.0	5.5	11.0	15.6	19.9	23.2	23.0	18.1	12.6	6.2	1.3
Adana	9.1	10.0	13.5	17.6	22.0	25.9	28.4	28.8	26.2	21.9	15.2	10.6
Pınarbaşı	-4.6	-3.8	1.8	7.7	12.1	16.0	19.5	19.6	14.9	9.7	3.2	-2.1
Tomarza	-5.3	-4.2	2.2	8.1	12.5	16.8	20.6	20.5	15.4	9.8	3.0	-2.6
Sarız	-4.2	-3.8	1.1	6.9	11.4	15.6	19.5	19.4	14.4	9.2	2.6	-2.4
Ulukışla	-2.4	-1.3	3.8	9.1	13.7	18.3	22.1	21.8	16.9	11.3	4.8	0.1
Karataş	9.9	10.7	13.9	17.3	21.2	24.8	27.3	28.0	25.8	22.0	16.0	11.4

Table 4.2. Monthly average total precipitation measured (1989-2008)

	Precipitation (mm)											
Months Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tufanbeyli	52.9	52.0	53.3	56.7	57.7	19.6	7.6	5.3	13.9	40.5	72.2	63.4
Gülek	90.7	67.3	62.7	74.4	54.1	30.6	10.4	11.8	20.4	40.3	85.7	141.9
Kayseri	27.2	33.0	39.1	53.1	60.5	32.6	10.4	7.5	12.6	31.5	34.4	40.9
Niğde	28.9	27.5	31.8	42.2	41.4	24.2	4.7	6.5	8.9	28.6	37.1	37.8
Adana	85.8	81.5	51.0	50.6	40.7	14.6	8.7	6.8	17.3	43.6	88.1	121.4
Pınarbaşı	26.6	33.6	42.1	51.8	54.8	34.6	8.4	8.3	14.5	38.0	40.7	40.0
Tomarza	31.7	34.9	39.4	52.6	56.9	30.2	6.2	8.9	13.8	33.7	41.7	40.3
Sarız	42.9	42.9	55.9	62.4	58.9	30.7	10.3	11.6	18.3	46.7	64.9	55.4
Ulukışla	23.8	20.6	32.9	43.8	47.7	25.9	7.9	6.2	9.2	27.4	30.5	35.5
Karataş	104.2	105.2	58.6	35.3	40.3	11.9	3.7	6.4	27.9	61.8	127.9	174.1

Table 4.3. Monthly average wind speed measured (1989-2008)

	Wind Speed (m/s)											
Months Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tufanbeyli	1.3	1.6	2.0	2.0	1.8	1.9	1.9	1.5	1.6	1.5	1.4	1.3
Gülek	1.7	1.6	1.6	1.6	1.5	1.6	1.6	1.5	1.6	1.5	1.5	1.6
Kayseri	1.4	1.7	2.1	2.3	1.8	1.8	1.8	1.6	1.6	1.5	1.4	1.4
Niğde	2.5	2.9	3.0	2.9	2.4	2.3	2.4	2.2	2.1	2.1	2.4	2.6
Adana	1.3	1.3	1.3	1.3	1.3	1.4	1.5	1.3	1.1	1.0	1.0	1.2
Pınarbaşı	3.9	4.3	4.4	4.4	3.8	3.6	3.9	3.6	3.4	3.4	3.8	3.7
Tomarza	2.0	2.4	2.9	3.2	2.7	2.8	3.1	2.8	2.3	2.1	2.2	2.0
Sarız	2.1	2.3	2.5	2.8	2.2	2.0	2.2	2.0	1.8	1.8	2.0	1.9
Ulukışla	3.2	3.3	3.4	3.5	2.9	2.9	3.0	2.8	2.6	2.5	2.9	3.2
Karataş	3.1	3.1	2.9	3.1	3.0	3.2	3.4	3.1	2.7	2.5	2.8	3.1

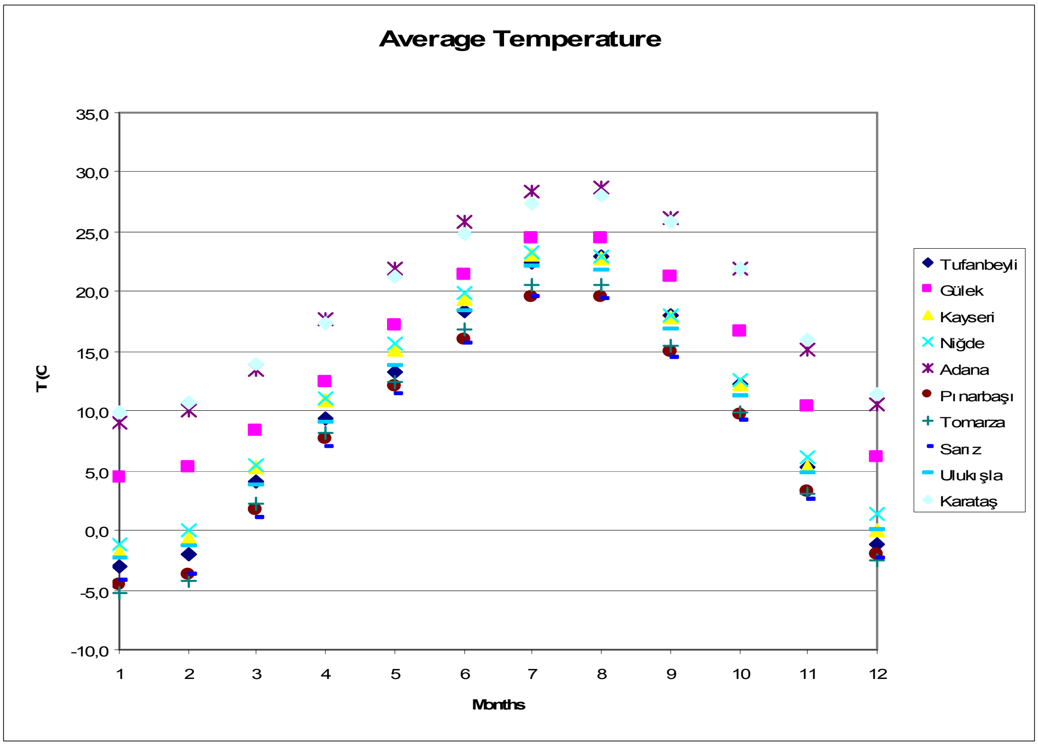

Figure 4.6. Monthly average temperature measured (1989-2008)

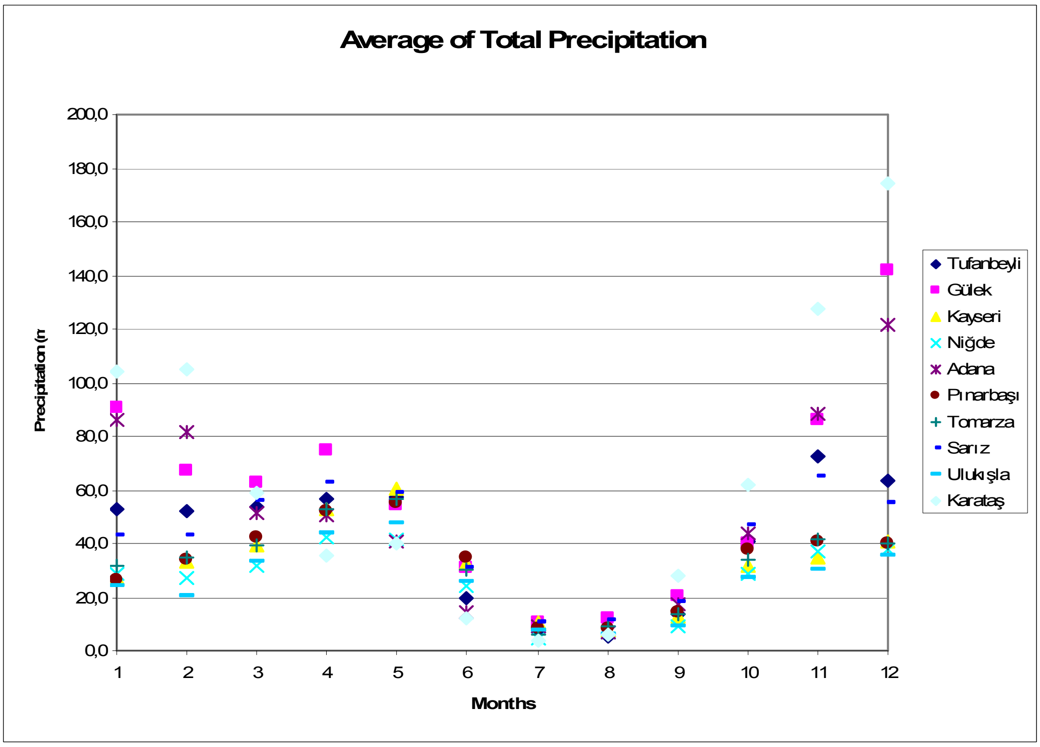

Figure 4.7. Monthly average total precipitation measured (1989-2008)

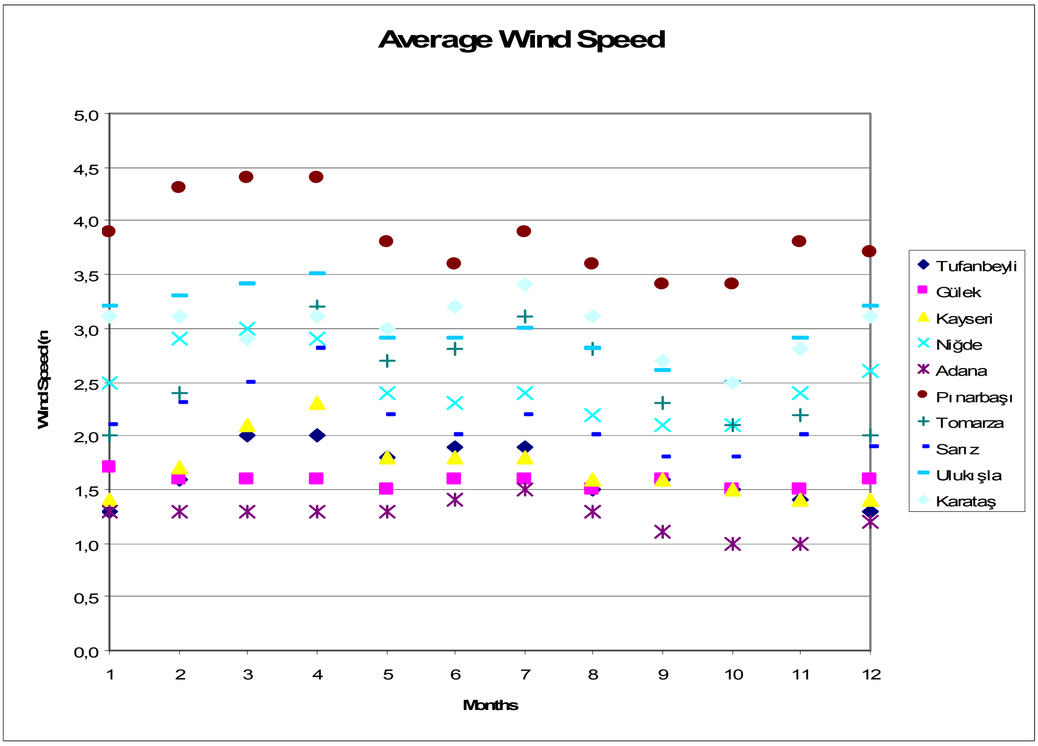

Figure 4.8. Monthly average wind speed measured (1989-2008)

As given in Figure 4.6, the temperature profiles are alike at different stations in the basin and outside the basin. At higher elevations, the temperatures are lower. Within a period of 20 years (1989-2008), the lowest average temperature at the basin was observed in Tomarza and Pınarbaşı stations in January as approximately -5^{o}C. These stations are located at the north of the basin at high elevations. The highest average temperature (28.8 ^{o}C) has been in July-August period in the vicinity of Adana. These averages are obtained using the temperatures measured during the day at 07:00, 14:00, and 21:00. Therefore, both nighttime and daytime temperatures are considered.

In addition to temperature, as seen in Figure 4.7, the precipitation profiles are also alike at different stations. Within the period of 1989-2008, the lowest average precipitation at the basin observed in Karataş in July as 3.7 mm, however, also the highest precipitation in the Basin during the same period is observed again in Karataş as 174.1 mm in December.

4.1.3. Water Quality

In this study different monitoring and sampling stations for water are used in order to develop an environmental pollution index. The locations of the stations are shown in Figure 3.4. In order to develop EPI, water quality data obtained from DSI taken into consideration. The water quality data obtained from DSI was compared with inland water sources quality criteria given in Table-1 of Regulation on Water Pollution Control, which is given in Appendix A. In this regulation inland water resources are classified in four classes where the first class is the best.

As discussed in Section 3.6, the water quality parameters that will be used for development of water pollution index are

- dissolved oxygen (DO),
- pH,
- 5-day biochemical oxygen demand (BOD_5),
- Nitrates (NO_3),
- total phosphates (PO_4),
- temperature (T),
- total solids (TS).

The annual average values of those mentioned parameters for the stations are given in Table 4.4. The measured values of the parameters are given in the figures in Appendix H.

Table 4.4. Annual average values of selected water quality parameters for the years 2004-2008

Station	***1801-Eğner***					***1804-Taşköprü***				
Parameter	*2008*	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO (mg/L)	9.00	8.38	8.83	8.45	7.78	9.03	7.90	8.93	8.33	7.88
pH	7.68	8.05	7.95	7.98	8.23	7.63	8.15	7.95	8.00	8.25
BOD_5 (mg/L)	0.85	1.13	0.55	1.03	0.68	2.33	1.55	0.98	1.75	1.05
NO_3 (mg/L)	1.36	0.77	0.89	0.93	0.63	0.50	0.50	0.62	0.82	0.59
PO_4 (mg/L)	N/A	0.00	N/A	0.00	0.00	N/A	0.26	N/A	0.02	0.03
T (°C)	15.50	15.50	16.00	15.63	16.00	17.25	19.00	18.00	17.00	20.00
TS (mg/L)	377.50	392.25	378.25	368.25	318.50	312.50	317.50	320.00	337.25	321.00
Station	***1805-Hacılı***					***1816-Nergizlik***				
Parameter	*2008*	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO (mg/L)	8.93	8.35	8.63	8.20	7.95	8.93	8.35	8.63	7.80	7.90
pH	7.75	8.05	8.00	8.08	8.25	7.88	8.10	8.00	8.13	8.25
BOD_5 (mg/L)	0.90	0.98	0.50	1.10	0.80	2.43	2.10	0.80	2.30	1.45
NO_3 (mg/L)	1.63	1.03	1.02	0.88	0.86	0.64	0.76	0.44	0.48	0.49
PO_4 (mg/L)	N/A	0.00	N/A	0.00	0.00	N/A	0.00	N/A	0.00	0.00
T (°C)	16.25	16.25	16.25	14.75	15.50	19.25	18.00	18.75	17.25	19.00
TS (mg/L)	371.75	327.25	338.00	362.25	302.50	317.50	327.50	309.50	368.50	313.00

Classification according to the Annex-1 of Regulation on Water Pollution Control

Class-I	Class-II	Class-III	Class-IV	No classification

Hence, Annex-1 of Regulation on Water Pollution Control does not include a standard for total solids, it includes a standard for total dissolved solids which is 500 mg/L for Class-I. Since all the total solids concentration is lower than the Class-I criteria of total dissolved solids, it can be concluded that total solids is also Class-I.

As seen in Table 4.4, dissolved oxygen concentration is lower than 8 mg/L, the limit value for Class-I, for all water quality monitoring stations in 2004; and same situation occurred in 2005 and 2007 for the stations Nergizlik and Taşköprü, respectively. The primary mechanisms that control the concentration of dissolved oxygen in water are re-aeration, photosynthesis, oxidation process, sediment and oxygen demand as well as pollution loads to the water bodies.

It is difficult to make a general comment on phosphate because of regular data deficiency. Nevertheless, there is significant increase in PO_4 concentrations in Taşköprü station, which is the lowest station (the nearest station to the tributary of the river) of four stations. The reason of this mentioned PO_4 high concentration might be agricultural residues or the waste of industry since the lower part of the Basin is rich in agriculture and industry.

The other parameters, parameters except DO and PO_4, are in the limits of Class-I for selected years and stations. In 2008 and 2006 all the parameter for all of the monitoring stations are satisfied the Class-I criteria.

4.1.4. Air Quality

In this study different monitoring and sampling stations for air are used in order to develop an environmental pollution index. The locations of the stations are shown in Figure 3.5. SO_2 and PM_{10} are chosen as quality parameters since they are the most common parameters measured in all the air quality monitoring stations. The annual average values of SO_2 and PM_{10} for the stations are given in Table 4.5. The daily values of the parameters are given in the figures in Appendix I and Appendix J.

Table 4.5. Annual average values of SO_2 and PM_{10} for air quality monitoring stations of MoEF

Parameter	**SO_2 (20 µg/m^3)**				**PM_{10} (40 µg/m^3)**			
Station	**2007**	**2008**	**2009**	**2010**	**2007**	**2008**	**2009**	**2010**
Adn-Çtl	N/A	0.47	1.47	0.04	N/A	42.20	37.07	16.42
Adn-Dgn	N/A	14.25	12.36	5.92	N/A	N/A	29.21	14.63
Adn-Met	1.99	4.83	8.04	6.63	107.46	72.54	61.11	54.80
Adn-Val	N/A	6.27	14.01	5.00	N/A	113.27	76.94	68.00
Aksaray	17.66	53.13	68.02	101.88	89.83	60.10	66.54	81.35
Hatay	4.64	11.09	7.49	13.81	108.84	98.00	89.94	91.42
K.Maraş	52.69	37.73	12.22	5.06	111.27	103.89	110.33	71.57
K.Mrş-Elb	55.32	23.04	6.53	14.65	123.76	136.03	107.95	124.94
Kayseri	10.17	8.21	3.83	15.58	74.79	94.76	59.29	58.10
Kys-Hur	23.05	35.80	12.72	44.13	70.87	95.20	71.89	85.82
Kys-Mel	3.26	13.56	8.44	30.94	52.29	69.33	50.20	60.59
Mersin	2.85	9.69	12.93	24.00	105.68	94.15	70.37	56.19
Nevşehir	12.14	45.83	22.85	36.97	97.93	68.82	49.50	49.41
Niğde	24.30	14.70	16.29	49.07	56.19	62.39	35.13	42.62
Osmaniye	2.42	5.34	3.62	6.74	84.32	93.74	86.62	106.57
Sivas	41.60	113.27	76.94	68.00	105.60	89.79	79.19	75.42

The grey cells in Table 4.5. show the values which are higher than the annual average standard limit, 20 µg/m^3 for SO_2, and 40 µg/m^3 for PM_{10}. The figures showing graphical representation of the SO_2 and PM_{10} values for the years are given in Figures 4.9, and 4.10., respectively.

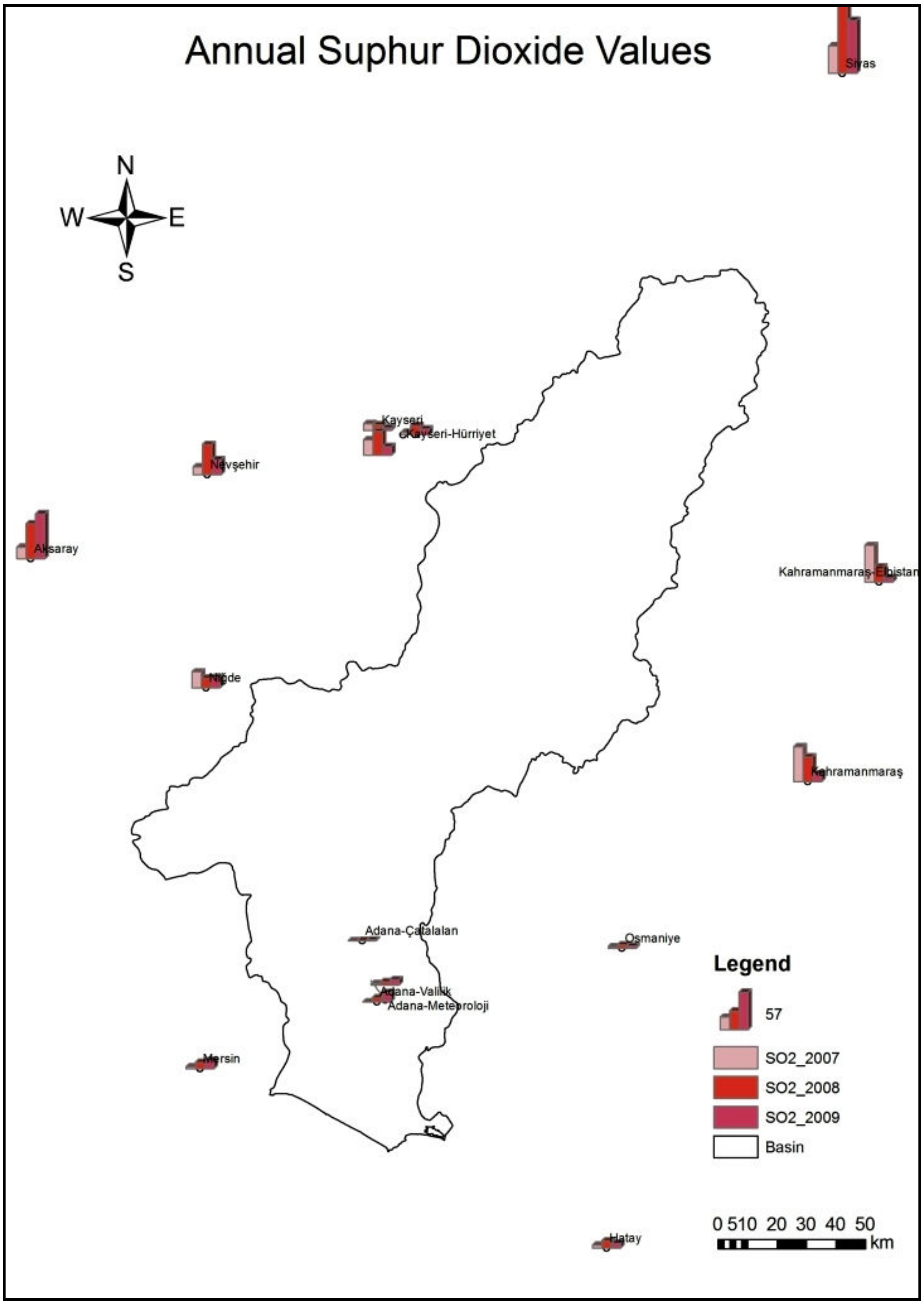

Figure 4.9. Annual SO_2 values measured in selected air quality monitoring stations for the years 2007-2009

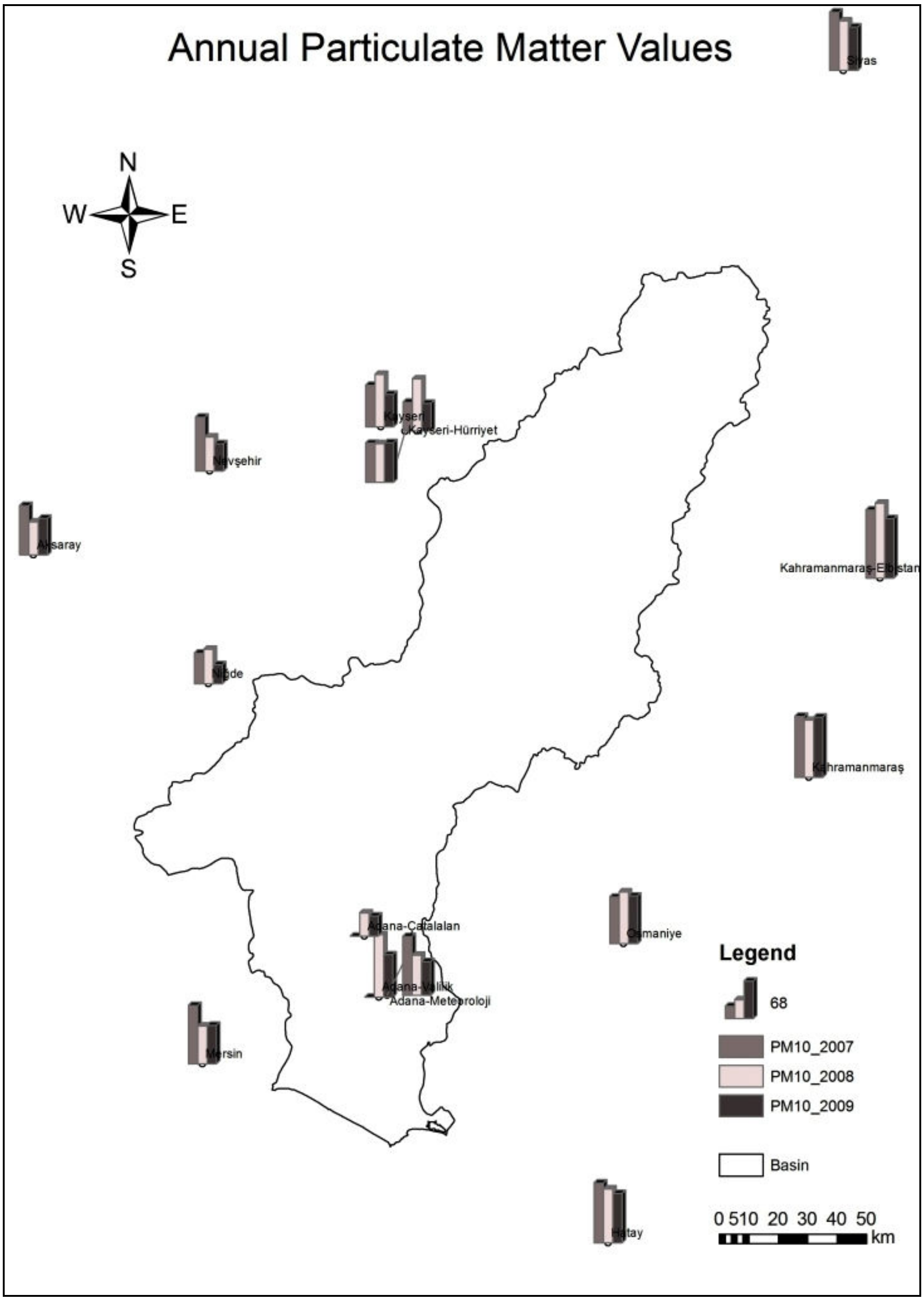

Figure 4.10. Annual PM_{10} values measured in selected air quality monitoring stations for the years 2007-2009

Sulphur dioxide (SO_2) is one of a group of highly reactive gasses known as "oxides of sulfur", which is an invisible gas having nasty and sharp smell. Natural sources of sulphur dioxide include releases from volcanoes, oceans, biological decay and forest fires. The most important man-made sources of sulphur dioxide are fossil fuel combustion, smelting, manufacture of sulphuric acid, conversion of wood pulp to paper, incineration of refuse and production of elemental sulphur. Coal burning is the single largest man-made source of sulphur dioxide accounting for about 50% of annual global emissions, with oil burning accounting for a further 25 to 30% (ACE, 2010). As seen in Table 4.5., and Figure 4.9; SO_2 concentrations are not in the allowed limits, 20μg/L annually, at Aksaray, Kahramanmaraş, Kahramanmaraş-Elbistan, Kayseri-Hürriyet, Kayseri-Melikgazi, Nevşehir, Niğde, and Sivas air quality monitoring stations; and significant increase in SO_2 concentrations in winter time can be seen from the graphs in Appendix I. Nearly all of the air qualities monitoring stations are in the city centers, the reasons of increase in winter time might be because of coal burning.

Particulate matter pollution consists of very small liquid and solid particles floating in the air. Greatest concerns to public health are the particles small enough to be inhaled into the deepest parts of the lung. These particles are less than 10 microns in diameter and are known as PM_{10}, which is a major component of air pollution that threatens both our health and our environment. As seen in Table 4.5., and Figure 4.10; PM_{10} concentrations nearly in all of the air quality monitoring stations are higher than the annual allowed limit, 40μg/L. It is only in the limits in Adana-Çatalalan and Adana-Doğankent limits, where there is less population and urbanization in those places. The major sources for higher particulate matters might be motor vehicles, wood burning stoves and fireplaces, dust from construction, landfills, and agriculture, wildfires and waste burning, industrial sources, windblown dust from open lands. These are all possible in the basin, but there is a significant increase in PM_{10} values in winter times at relatively colder places such as Kahramanmaraş and Sivas. This might be because of wood or coal burning.

4.2. ENVIRONMENTAL POLLUTION INDEX

In Section 3.6 development of water and air pollution indices and combining them to develop an environmental index are discussed. In the following sections, the results of index development are given.

4.2.1. Water Pollution Index

In this study, it is decided that to use "weighted linear sum aggregation function" as aggregation function for water pollution index, can be represented as

$$WPI = \sum_{i}^{n} w_i q_i \qquad (3.2)$$

where WPI: weighted arithmetic mean water pollution index; w_i: weighting factor for the i^{th} variable; q_i: subindex value of the i^{th} pollutant variable; and n: number of pollutant variables.

The parameters used for water quality index development by NSF are taken as a base for selection of water quality parameters which are used in this study. While selecting the parameters availability of parameters and standards are taken into consideration, and so following 6 parameters are selected:

- dissolved oxygen,
- pH,
- 5-day biochemical oxygen demand,
- nitrates,
- temperature,
- total solids.

After the selection of parameters, the next step is assignment of weights for the selected pollutant variables. The weights of selected parameters are assigned according to the weights used by NSF, and if any of the parameters mentioned by NSF is not used for index development in this study because of data deficiency, the weights of the unused parameters are distributed equally to the weights of used ones. For the selected water quality monitoring stations, fecal coliform and turbidity measurements are not present for all the years, and total phosphates (PO_4) data are not present for the years 2006 and 2008. The original and modified weights of parameters are given in Table 4.6. The grey cells in Table 4.6. show the data deficiency on the selected parameters.

Table 4.6. Weights of parameters used by NSF and modified weights

#	**Parameters**	**Weights. w_i (Original)**	**Modified Weights. w_i (omitting FC+Turb+PO_4)**
1	Dissolved Oxygen	0.17	0.225
2	Fecal Coliform	0.15	
3	pH	0.12	0.175
4	BOD_5	0.10	0.155
5	Nitrates	0.10	0.155
6	Phosphates	0.10	
7	Temperature	0.10	0.155
8	Turbidity	0.08	
9	Total Solids	0.08	0.135
Total		***1.00***	***1.000***

In NSF water quality index the sub-index values are extracted from the quality graphics elaborated for each parameter. However, in these graphics, dissolved oxygen value is given in percent, but the values obtained from DSI are in concentration. So, in order to interpret sub-index for DO, sub-index evaluation for concentration given by Pesce and Wunderlin (2000) is used. Sub-index values (q_i) for the selected parameters measured in selected stations for the years 2004-2008 are shown in Table 4.7. Although sub-index value for PO_4 is given in Table 4.7, it is not taken into consideration for EPI calculation in order to have consistency with EPI of different years.

Table 4.7. Sub-index values (q_i) for the selected parameters measured in selected stations for the years 2004-2008

Station	***1801-Eğner***					***1804-Taşköprü***				
Parameter	*2008*	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO	100	100	100	100	100	100	100	100	100	100
pH	91	82	86	85	76	92	79	86	84	75
BOD_5	96	94	98	95	97	74	89	95	85	95
NO_3	96	96	96	96	96	97	97	96	96	96
PO_4	No data	100	No data	100	100	No data	86	No data	99	99
T	30	30	29	30	29	27	24	26	27	22
TS	49	48	49	51	57	58	57	57	55	57
Station	***1805-Hacılı***					***1816-Nergizlik***				
Parameter	*2008*	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO	100	100	100	100	100	100	100	100	100	100
pH	91	82	84	81	75	88	80	84	80	75
BOD_5	96	95	98	94	96	72	78	96	74	91
NO_3	96	96	96	96	96	96	96	97	97	97
PO_4	No data	100	No data	100	100	No data	100	No data	100	100
T	29	29	29	32	30	23	26	24	27	24
TS	50	56	55	51	59	57	56	58	51	58

According to Regulation on Water Pollution Control (Appendix A) nearly all the water quality parameters are Class-I, however their sub-index value are not as good as it is.

Determination of sub-index values for selected parameters is followed by calculation of WPI by weighted arithmetic mean function. Firstly, weights of the parameters (w_i) are multiplied with the sub-indices (q_i), and then the results of these multiplications are added to calculate WPI for Seyhan River Basin. The results of the calculations are given in Table 4.8.

Table 4.8. Multiplication of weights (w_i) and sub-index values (q_i) for the selected parameters for the years 2004-2008

	1801-Eğner					***1804-Taşköprü***				
	2008	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
pH	15.93	14.35	15.05	14.88	13.30	16.10	13.83	15.05	14.70	13.13
BOD_5	14.88	14.57	15.19	14.73	15.04	11.47	13.80	14.73	13.18	14.73
NO_3	14.88	14.88	14.88	14.88	14.88	15.04	15.04	14.88	14.88	14.88
T	4.65	4.65	4.50	4.65	4.50	4.19	3.72	4.03	4.19	3.41
TS	6.62	6.48	6.62	6.89	7.70	7.83	7.70	7.70	7.43	7.70
Σ	***79.45***	***77.43***	***78.73***	***78.52***	***77.91***	***77.12***	***76.57***	***78.88***	***76.87***	***76.34***
	1805-Hacılı					***1816-Nergizlik***				
	2008	*2007*	*2006*	*2005*	*2004*	*2008*	*2007*	*2006*	*2005*	*2004*
DO	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
pH	15.93	14.35	14.70	14.18	13.13	15.40	14.00	14.70	14.00	13.13
BOD_5	14.88	14.73	15.19	14.57	14.88	11.16	12.09	14.88	11.47	14.11
NO_3	14.88	14.88	14.88	14.88	14.88	14.88	14.88	15.04	15.04	15.04
T	4.50	4.50	4.50	4.96	4.65	3.57	4.03	3.72	4.19	3.72
TS	6.75	7.56	7.43	6.89	7.97	7.70	7.56	7.83	6.89	7.83
Σ	***79.43***	***78.51***	***79.19***	***77.97***	***78.00***	***75.20***	***75.06***	***78.67***	***74.08***	***76.32***

Finally after the summation of the multiplied results water quality indices are calculated, and classified according to again NSF as discussed in Section 3.6. The indices are given Table 4.9 and graphically represented in Figure 4.11.

Table 4.9. Water Pollution Indices and Classification

Station	2004	2005	2006	2007	2008
Eğner	78	79	79	77	79
Taşköprü	76	77	79	77	77
Hacılı	78	78	79	79	79
Nergizlik	76	74	79	75	75

Classification of Water Pollution Indices

100-91 Excellent	90-71 Good	70-51 Regular	50-26 Bad	25-0 Very Bad

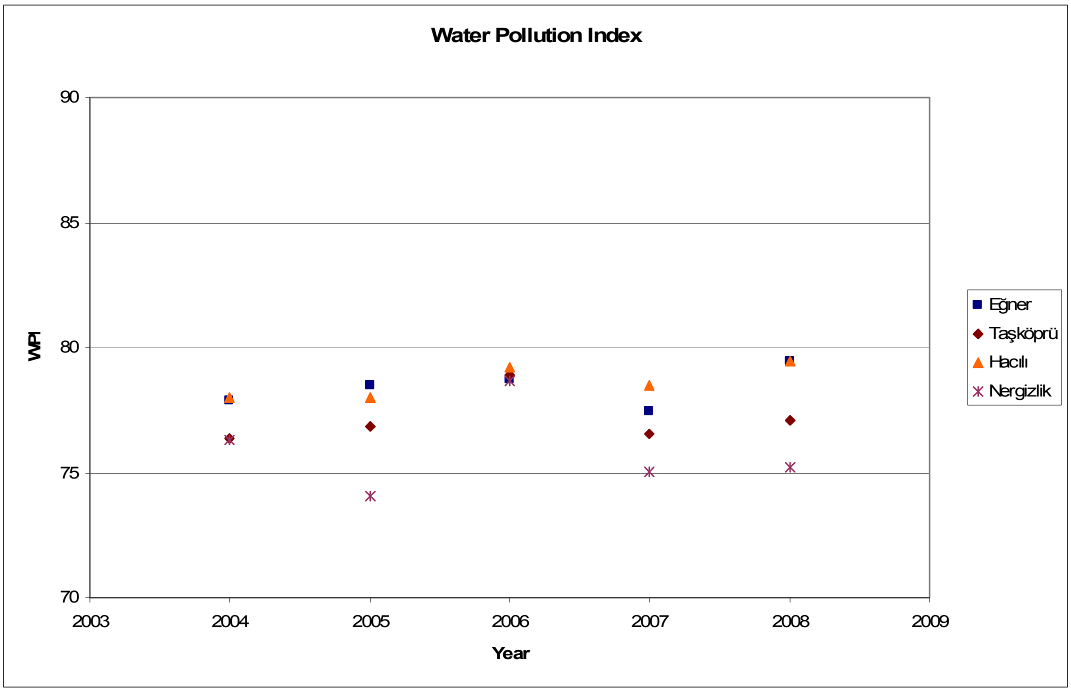

Figure 4.11. Water Pollution Indices

As seen in Table 4.9., and Figure 4.11., all of the developed indices are between the range of 71-80, particularly between 75-80. The indices have their lowest value in 2008 among the selected years, and in most of the years Nergizlik has the lowest index, showing that lowest quality. According to the calculated water quality indices, one might be concluding that the degree of water quality in the middle section of Seyhan Basin is "good". When Figure 4.11 is examined, it can be seen that there is a stable trend in WPI, but actual trend can be determined by continuing such a monitoring study. The water quality is not in the excellent class, therefore, if precautions are not taken, the water quality can be deteriorated in future. Therefore, actions should be taken to decrease the pollution loads for the studies water quality parameters. It must also be reminded that there is no water quality station in the lower part of the basin (south to Adana) where highest pollution can be expected. Therefore, the results obtained in this study are limited with the locations of the monitoring stations.

4.2.2. Air Pollution Index

In this study, it is decided to use "weighted linear sum aggregation function" as aggregation function for air pollution index, can be represented as

$$WPI = \sum_{i}^{n} w_i q_i \qquad (3.2)$$

where *WPI*: weighted arithmetic mean air pollution index; w_i: weighting factor for the i^{th} variable; q_i: subindex value of the i^{th} pollutant variable; and n: number of pollutant variables. Because of available data SO_2 and PM_{10} are selected as pollutant variables, and as mentioned in Section 3.6.2 the weights (w_i) of SO_2 and PM_{10} are calculated as 0.389 and 0.611, respectively.

The sub-index values (q_i) are determined according to the standard concentrations and breakpoints as given in Table 3.10. Sub-index values (q_i) for the selected parameters measured in selected air quality monitoring stations for the years 2007-2009 are shown in Table 4.10

Table 4.10. Sub-index values (q_i) for the selected parameters measured in selected air quality monitoring stations for the years 2007-2009

Parameter	**SO_2**			**PM_{10}**		
Station	*2007*	*2008*	*2009*	*2007*	*2008*	*2009*
Adana-Çatalalan	No data	5	6	No data	27	9
Adana-Doğankent	No data	16	14	No data	No data	7
Adana-Meteoroloji	6	9	11	62	55	52
Adana-Valilik	No data	10	16	No data	63	56
Aksaray	18	33	37	58	52	53
Hatay	8	13	11	62	60	58
Kahramanmaraş	33	29	14	63	61	63
Kahramanmaraş-Elbistan	33	26	10	65	68	62
Kayseri	13	11	8	55	59	52
Kayseri-Hürriyet	26	29	15	54	59	55
Kayseri-Melikgazi	7	15	11	50	54	50
Mersin	7	12	15	62	59	54
Nevşehir	14	31	26	60	54	33
Niğde	26	16	17	51	53	9
Osmaniye	7	9	8	57	59	58
Sivas	30	47	39	62	58	56

Table 4.11. Multiplication of weights (w_i) and sub-index values (q_i) for the selected parameters for the years 2004-2008

Parameter	SO_2 (w_{SO2}=0.389)			PM_{10} (w_{PM10}=0.611)		
Station	*2007*	*2008*	*2009*	*2007*	*2008*	*2009*
Adana-Çatalalan		2	2		16	23
Adana-Doğankent		6	6			18
Adana-Meteoroloji	3	3	4	38	33	37
Adana-Valilik		4	6		39	47
Aksaray	7	13	14	36	32	41
Hatay	3	5	4	38	37	55
Kahramanmaraş	13	11	6	38	37	67
Kahramanmaraş-Elbistan	13	10	4	40	42	66
Kayseri	5	4	3	34	36	36
Kayseri-Hürriyet	10	11	6	33	36	44
Kayseri-Melikgazi	3	6	4	31	33	31
Mersin	3	5	6	38	36	43
Nevşehir	5	12	10	37	33	30
Niğde	10	6	7	31	32	21
Osmaniye	3	4	3	35	36	53
Sivas	12	18	15	38	36	48

Finally after the summation of the multiplied results air pollution indices are calculated, and classified. The classified indices are given Table 4.12, and graphically represented in Figure 4.12.

Table 4.12. Air Pollution Indices and Classification

Station	*2007* $\sum(w_i \times q_i)_{2007}$	*2008* $\sum(w_i \times q_i)_{2008}$	*2009* $\sum(w_i \times q_i)_{2009}$
Adana-Çatalalan		18	25
Adana-Doğankent		6	23
Adana-Meteoroloji	40	37	42
Adana-Valilik		42	53
Aksaray	43	45	55
Hatay	41	42	59
Kahramanmaraş	51	49	73
Kahramanmaraş-Elbistan	53	52	70
Kayseri	39	41	39
Kayseri-Hürriyet	43	48	50
Kayseri-Melikgazi	34	39	35
Mersin	40	41	49
Nevşehir	42	45	40
Niğde	41	38	28
Osmaniye	38	40	56
Sivas	49	54	63

Classification of Air Pollution Indices

0-25 Good quality	*26-50 Low pollution*	*51-70 Moderate pollution*	*71-85 Unhealthy for sensitive groups*	*86-100 unhealthy*

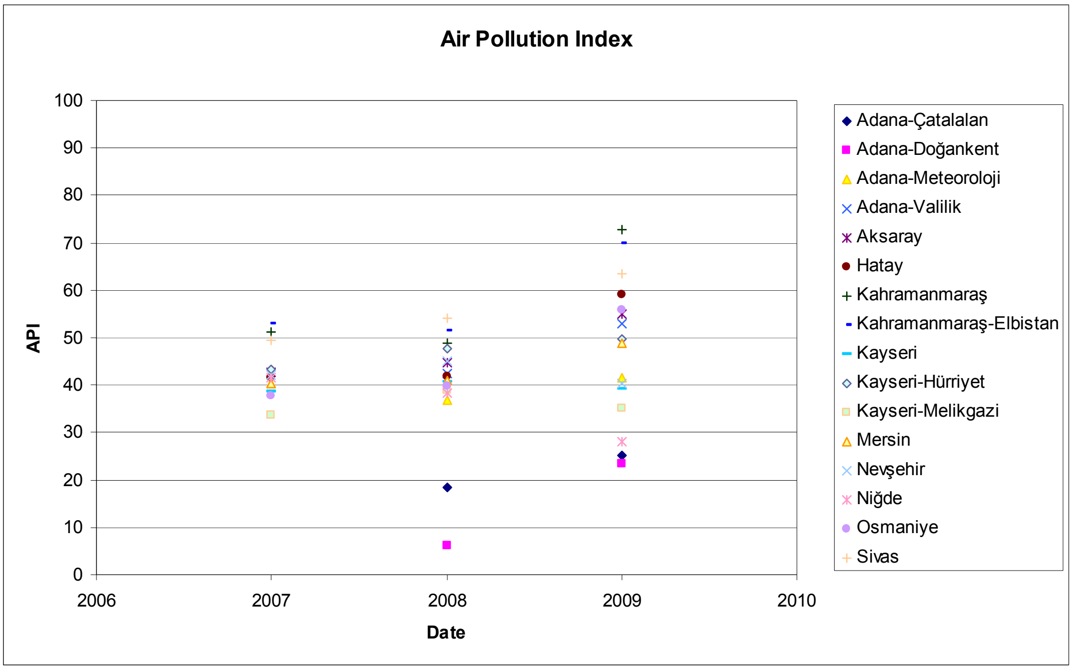

Figure 4.12. Air Pollution Indices

As seen in Table 4.12. and Figure 4.12, majority of the air pollution indices for the selected stations remains in the range of 26-50 which shows low pollution. While pollution status in Çatalalan and Doğankent stations is in good status, it is in moderate pollution status Kahramanmaraş, Kahramanmaraş-Elbistan, and Sivas air monitoring stations. It is also noticed that there is a significant increase in the year 2009, while there is not a significant change for the years 2007 and 2008. However, when Figure 4.12 examined, it can be seen that there is an increasing trend in API, which mean increasing pollution. Therefore, if precautions are not taken, the air quality can be deteriorated in future. So, actions should be taken to decrease the pollution loads for the studies air quality parameters. Although the majority of air pollution indices are in low or moderate pollution class, the indices calculated for Adana-Çatalalan and Adana-Doğankent stations remain in the range of 0-25 showing good quality. The reason of this might be location of the stations, locations with less population and less human activity. Another reason might be the location of the stations which can be effected by air streams. The highest air pollution index calculated in Kahramanmaraş-Elbistan, might be because of coal burning electrical power station and coal burning for heating. Same could be concluded for Sivas monitoring station.

4.2.3. Environmental Pollution Index

Following development of WPI and API, an environmental pollution index (EPI) is developed for Seyhan Basin. Data used for determination of EPI gathered from water and air monitoring stations pollution indices. As mentioned in Chapter 3, WPI developed for the years 2004-2008 and API for the years 2007-2009 because of the data availability. Although API is calculated for year 2007 for the existing stations, the number of air quality monitoring stations is a few. So, air quality data for the year 2007 could not be taken into consideration for calculation of EPI, and EPI is developed only for the year 2008, which both water and air indices and data available.

In order to combine WPI and API to develop an EPI, weighted root sum aggregation function, is used as in WPI and API development. In this development weights of WPI and API are taken equal, that is 0.50 for each of the indices.

A critical point in EPI development in this study is to estimate the air pollutant values at water quality monitoring stations since the locations of monitoring stations are different. In order to estimate concentration of air pollutant variables at water quality monitoring stations, inverse distance weighted method is used. By this method, measured values of air pollutant variables interpolated to the location where water quality monitoring stations are. The result of inverse distance weighted method is shown in Figure 4.13.a, and Figure 4.13.b, respectively for SO_2 and PM_{10}. The values of the pollutant variables at water quality monitoring stations for year 2008 are interpolated from the Figures 4.13.a and 4.13.b, respectively for SO_2, and PM_{10}. The interpolated values together with measured water quality parameters are given in Table 4.13.

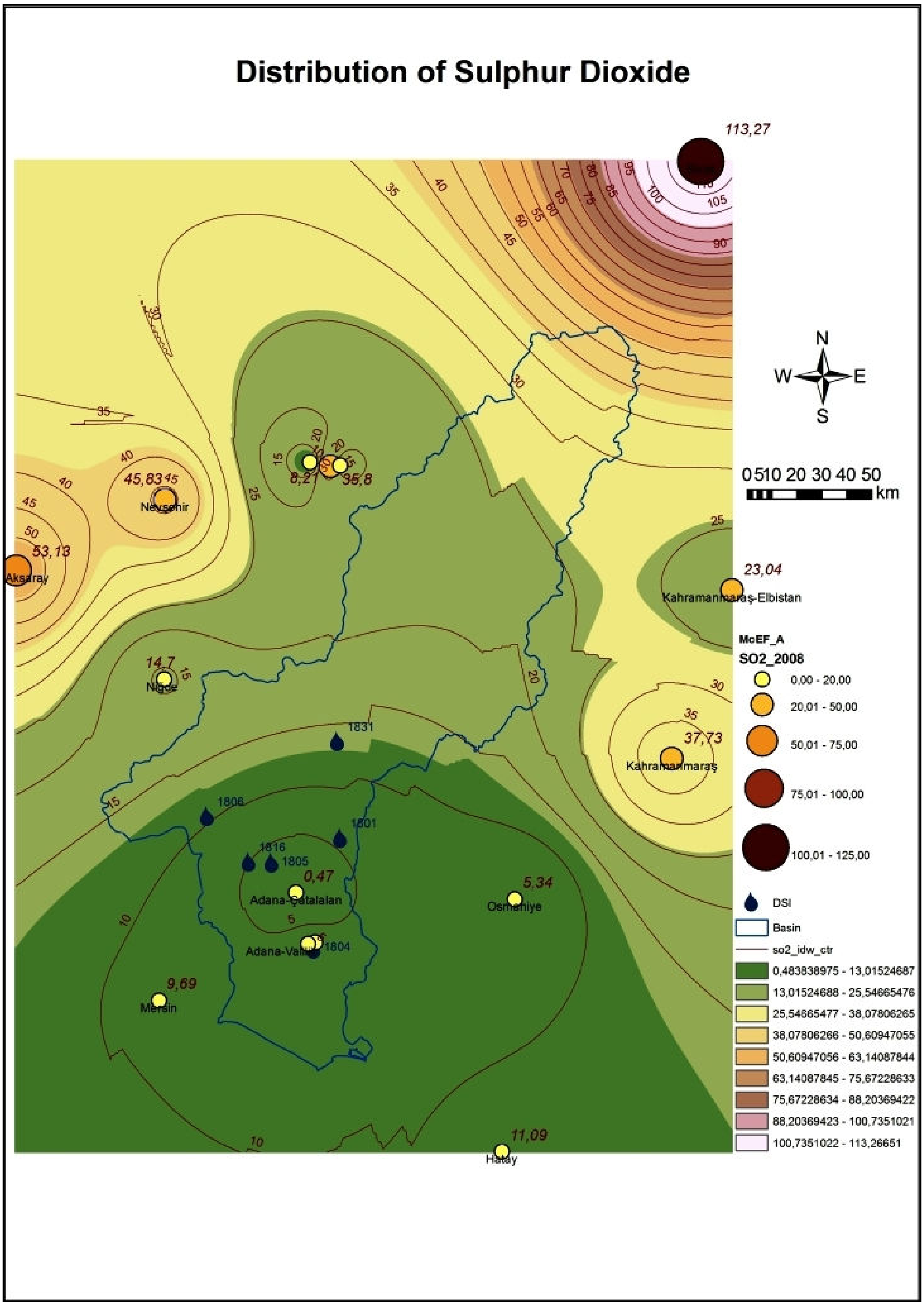

Figure 4.13.a. Result of Inverse Distance Method used for Determination of SO_2 Values for the Year 2008

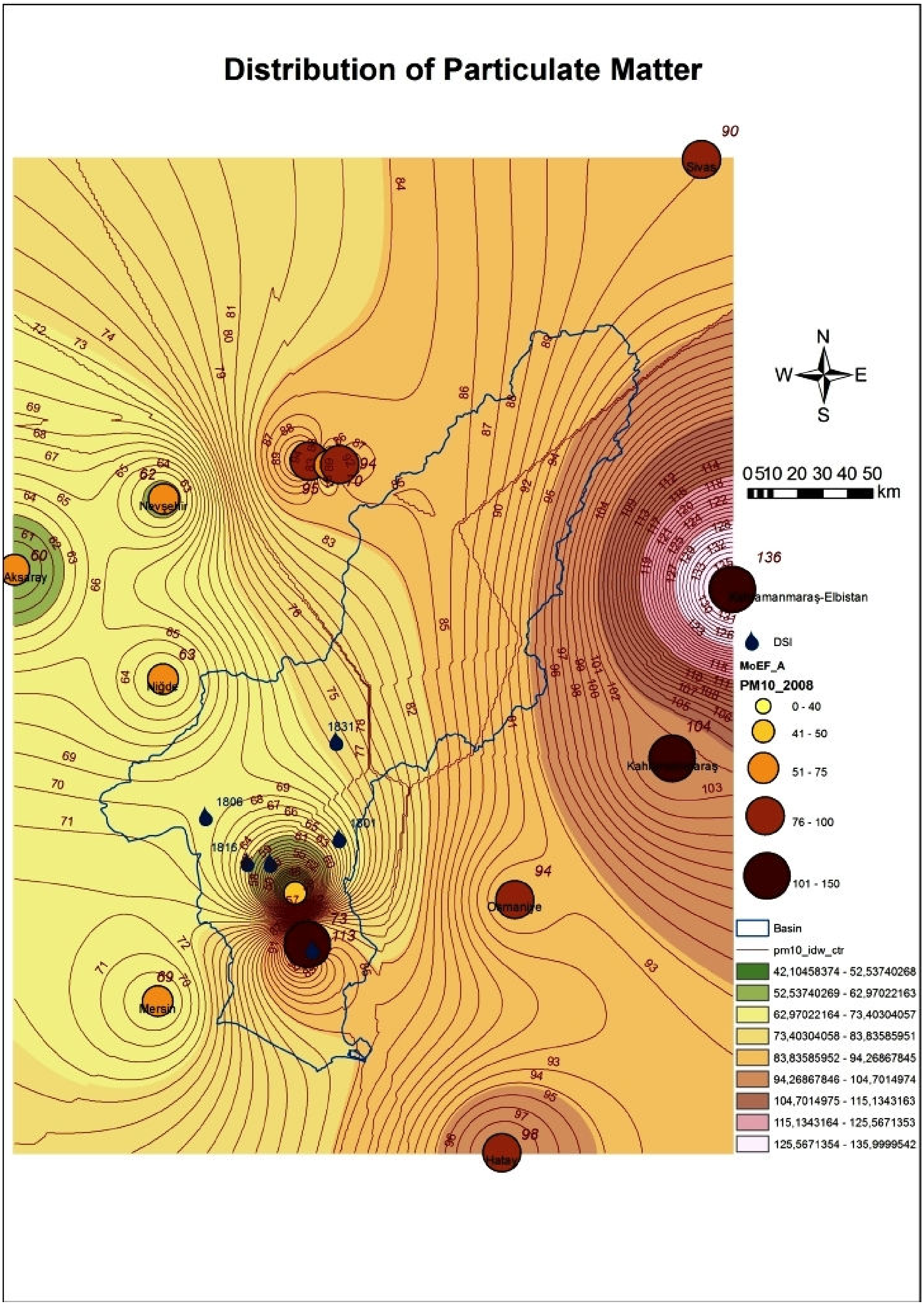

Figure 4.13.b. Result of Inverse Distance Method used for Determination of PM_{10} Values for the Year 2008

Table 4.13. Interpolated Values of Air Quality Parameters and Measured Values of Water Quality Parameters for the Year 2008

	Water							***Air***	
Station	DO (mg/l)	pH	BOD_5 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	T (°C)	TS (mg/l)	*SO_2 (mg/l)*	*PM_{10} (mg/l)*
Eğner	9.00	7.68	0.85	1.36	No data	15.50	377.50	*5.5*	*70*
Taşköprü	9.03	7.63	2.33	0.50	No data	17.25	312.50	*5.5*	*89*
Hacılı	8.93	7.75	0.90	1.63	No data	16.25	371.75	*3*	*58*
Nergizlik	8.93	7.88	2.43	0.64	No data	19.25	317.50	*5*	*64*

Afterwards, by "weighted linear sum aggregation function" as discussed in Section 3.6.1, water pollution index; and again by "weighted linear sum aggregation function" as discussed in Section 3.6.2, air pollution index is developed for year 2008. Note that, air pollution index is developed with interpolated values. The developed water and air pollution indices are shown in Table 4.14. and Table 4.15, respectively.

Table 4.14. Water Pollution Index (2008)

Station		**Eğner**		**Taşköprü**		**Hacılı**		**Nergizlik**	
Para.	w_i	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$
DO	*0.23*	100	22.50	100	22.50	100	22.50	100	22.50
pH	*0.18*	91	15.93	92	16.10	91	15.93	88	15.40
BOD_5	*0.16*	96	14.88	74	11.47	96	14.88	72	11.16
NO_3	*0.16*	96	14.88	97	15.04	96	14.88	96	14.88
T	*0.16*	30	4.65	27	4.19	29	4.50	23	3.57
TS	*0.14*	49	6.62	58	7.83	50	6.75	57	7.70
WPI		***79***		***77***		***79***		***75***	

Table 4.15. Air Pollution Index (2008)

Station		**Eğner**		**Taşköprü**		**Hacılı**		**Nergizlik**	
Para.	w_i	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$	q_i	$w_i \times q_i$
SO_2	*0,39*	9	2	9	2	7	1	9	2
PM_{10}	*0,61*	54	33	58	36	52	32	53	32
API		***35***		***38***		***33***		***34***	

Development of WPI and API is followed by development of EPI. As mentioned before, in this development weights of WPI and API are taken equal, since it was not possible to obtain a ration in the literature. The critical point here is the water pollution index is a decreasing scale index, thereby a lower index value indicates a poorer water quality, whereas air pollution index is an increasing scale index. In this case an aggregation method based on linguistic interpretation. According to the present water and air quality indices, a matrix including both of the indices is developed as discussed in Section 3.6.3. Here, the EPI is defined as linguistic variables with five linguistic terms *excellent, good, moderate, bad*, and *very bad*.

The WPI and API for the year 2008 are summarized in Table 4.16, and corresponding EPI is determined from Figure 4.14. The classification of the indices given in Table 4.16 is shown via colors.

Table 4.16. Water and air quality indices and corresponding environmental pollution index for the year 2008

Station	**Eğner**	**Taşköprü**	**Hacılı**	**Nergizlik**
WPI	79	77	79	75
API	35	38	33	34
EPI	good	good	good	good

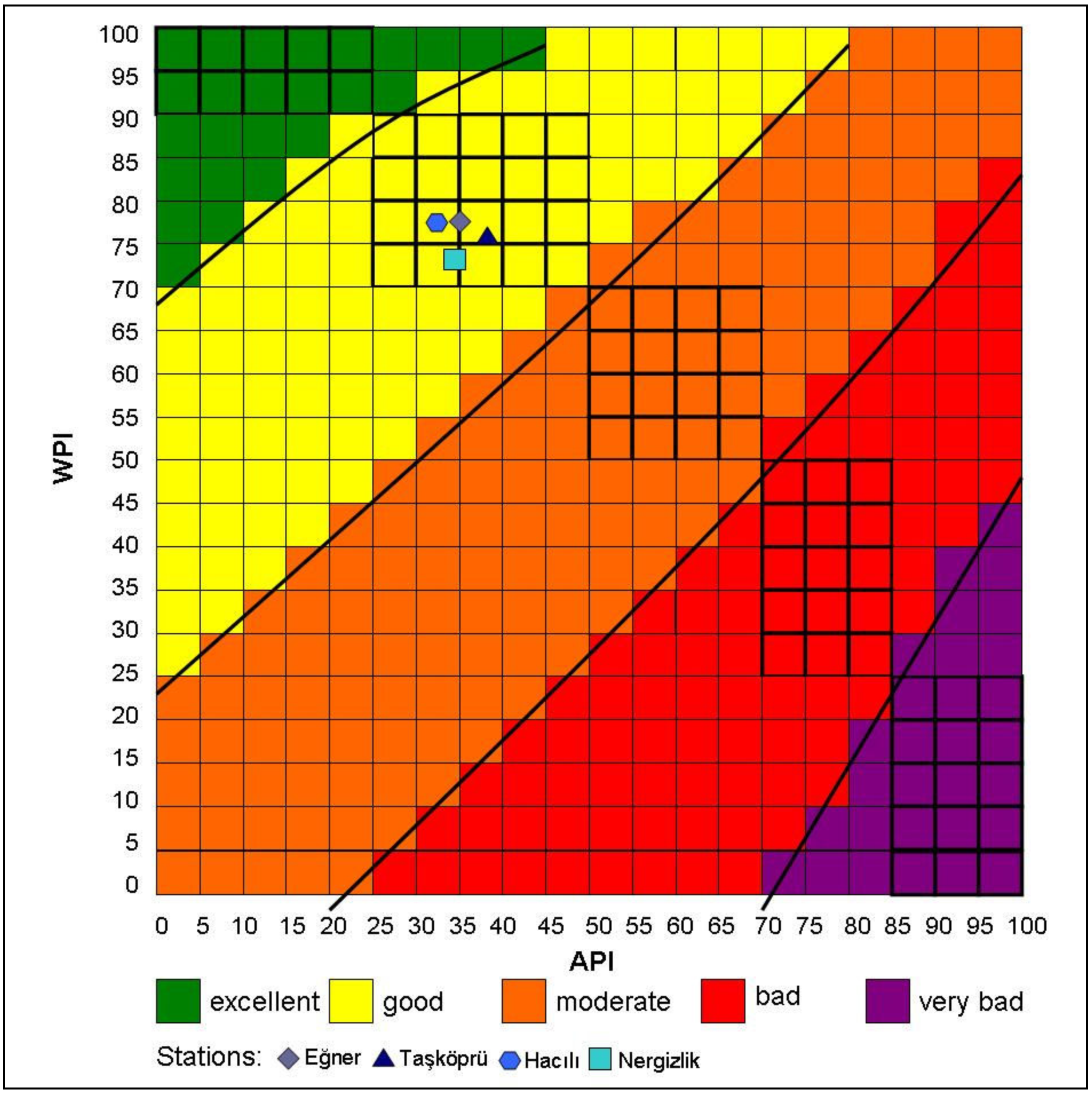

Figure 4.14. Environmental pollution index at Seyhan River Basin for the year 2008

The water, air, and environmental quality indices developed for Seyhan Basin for the year 2008 are shown in Table 4.16, and Figure 4.11. According to the calculated indices WPI is classified as “good”, and API is classified as “low pollution”. According to calculated WPI and API, EPI is determined as “good” in the middle section of the Seyhan Basin.

In addition to graphical and linguistic determination of EPI, another method based on weighted on arithmetic mean aggregation function is used for EPI development. The weighted arithmetic mean aggregation function includes weight of a variable,

w_i, and sub-index value for that variable, q_i. The calculations of EPI for the Basin by using the selected data for year 2008 are summarized in Table 4.17.

Table 4.17. Environmental Pollution Index (2008)

Station		Eğner	Taşköprü	Hacılı	Nergizlik
WPI	WPI	79	77	79	75
	w_{WPI}	0.5	0.5	0.5	0.5
	q_{WPI}	4	4	4	4
API	API	35	38	33	34
	w_{API}	0.5	0.5	0.5	0.5
	q_{API}	4	4	4	4
EPI		4	4	4	4
Classification of Environmental Pollution Index					
4<EPI≤5 (Excellent)	3<EPI≤4 (Good)	2<EPI≤3 (Moderate)	1<EPI≤2 (Bad)	EPI=1 (Very bad)	

According to calculated WPI and API, EPI is calculated and obtained the index equal to 4, which is classified as “good”. As given above paragraphs same EPI value is obtained in both of the EPI development methods.

This situation shows that, there are some problems on environment since the EPI is not the class of excellent. Necessary precautions required to be taken in order to save the good situation or improve it.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

Usually one single index, only water or only air quality index, is not sufficient to determine the situation of the environment. To tackle with this problem, environmental pollution index (EPI) is developed, which allows the evaluation of the degree of environmental quality or pollution induced by certain activities. Traditionally, an EPI is an algorithm that expresses a measurement of the environment's qualitative state. The final result usually is a unique symbol or a simple combination of numerical and alphanumerical variables. It is a simplified expression of a complex combination of several factors and its relevance depends on its reliability and the quantity of information it provides. Most EPIs use parameters, weightings, rating curves, and aggregation methods (Pykh *et al.*, 2000).

In this study, EPI for the middle section Seyhan River Basin, which is located on the Eastern Mediterranean part of Turkey, is developed for the year 2008. Data used in this study is composed of water and air quality data, meteorological data, and land cover data in addition to the DEM of the basin. DEM is used to delineate the Seyhan Basin, water and air quality data in order to develop water, air, and environmental indices, and other data for database and interpret the results.

In the study, all of the developed water quality indices are between the range of 71-80, particularly between 75-80. The indices have their lowest value in 2008 among the selected years, and in most of the years Nergizlik has the lowest index, showing that lowest quality. According to the calculated water quality indices, one might be concluding that the degree of water quality in the middle section of Seyhan Basin is “good”.

On the other hand, majority of the air pollution indices for the selected stations remains in the range of 26-50 which shows low pollution. While pollution status in Çatalalan and Doğankent stations is in good status, it is in moderate pollution status Kahramanmaraş, Kahramanmaraş-Elbistan, and Sivas air monitoring stations. It is also noticed that there is a significant increase in the year 2009, while there is not a significant change for the years 2007 and 2008. Although the majority of air pollution indices are in low or moderate pollution class, the indices calculated for Adana-Çatalalan and Adana-Doğankent stations remain in the range of 0-25 showing good quality. The reason of this might be location of the stations, locations with less population and less human activity. The highest air pollution index calculated in Kahramanmaraş-Elbistan, might be because of coal burning electrical power station and coal burning for heating. Same could be concluded for Sivas monitoring station.

When water and air quality indices are examined, it can be seen that they are classified as “good” and “low pollution”, respectively. However, there is a stable trend in WQI, and an increasing trend in API, which shows decreasing quality (increasing pollution). Therefore, if precautions are not taken, the environmental quality can be deteriorated in future. Therefore, actions should be taken to decrease the pollution loads.

After determination of water and air quality indices EPI is developed for the year 2008, the year that both water and air quality data are present. EPI is developed by two aggregation methods, one based on linguistic interpretation and the other on weighted arithmetic mean function. According to the calculated indices with both of the aggregation methods EPI is determined as “good” in the middle section of Seyhan Basin. This situation shows that, the situation of the environment is good;

however there are traces of pollution. Necessary precautions required to be taken in order to protect the good situation or improve it.

The obtained pollution indices could be used for determination of the situation of the environment and monitor the trend, the change in the situation of environment in time, to support environmental decision makers, and to inform public about quality of environment of the country.

5.2. RECOMMENDATIONS FOR FUTURE STUDY

In this study, the calculations are performed with limited data. With advancement of data production (e.g. increasing number of quality monitoring stations, and increase the monitoring period especially for water) in future, quality indices could be determined more precisely. Also, by an ongoing monitoring, the environmental quality of the Basin would be compared with the previous situation in order to determine the trend of the environment.

The results obtained in this study are based on water quality analysis carried by DSI, air quality analysis performed by MoEF, and land cover classification. More analysis on water and air quality and specific determination of land use in addition to land cover will give more precise results. Future studies may focus on more data and significance of different land use activities.

The lower parts of the Seyhan Basin are highly industrialized and the receiving body for wastes of those industrial activities is a water body, either a river or a channel, which ends at the sea. So, improving the index effectiveness in terms of toxicity is an important upgrade, especially for the lower part of the Basin which receives high amounts of industrial discharges. For this purpose, an aggregate index based on selected heavy metals can be introduced in further studies.

In this study, EPI is developed by two aggregation methods, one based on linguistic interpretation and the other on weighted arithmetic mean function. Although, both of the methods give same result, the second method will be more useful if the weights of the water and air quality indices are not equal due to the area. In addition, this method can relatively easily be updated if another index, such as soil pollution, included in order to obtain a more precise environmental quality index. This method also allows assignment of varying weights for different environmental indices.

Finally, the presented environmental pollution index can be extended for soil pollution too, obtaining in this way a complete environmental pollution index. The index may then be used for quantification of the environment, health, determining the effectiveness, and comparing alternative plans and policies in order to help environmental decision-makers.

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APPENDIX A

QUALITY CRITERIA OF INLAND WATER SOURCES

Table A.1. Quality Criteria of Inland Water Resources (Regulation on Water Pollution Control; O.G. 31.12.2004 / 25687)

	WATER QUALITY CLASSES			
PARAMETER OF WATER QUALITY	I	II	III	IV
A) Physical and inorganic-chemical Parameters				
1) Temperature (^oC)	25	25	30	> 30
2) pH	6.5-8.5	6.5-8.5	6.0-9.0	Out of 6.0-9.0
3) Saturated oxygen (mg O_2/L)	8	6	3	< 3
4) Oxygen saturation (%)	90	70	40	< 40
5) Chlorur ion (mg Cl^-/L)	25	200	400[b]	> 400
6) Sulphat Ion (mg $SO_4^=$/L)	200	200	400	> 400
7) Ammonium nitrogen (mg NH_4^+-N/L)	0.2[c]	1[c]	2[c]	> 2
8) Nitrite nitrogen (mg NO_2^--N/L)	0.002	0.01	0.05	> 0.05
9) Nitrate nitrogen (mg NO_3^--N/L)	5	10	20	> 20
10) Total phophorus (mg P/L)	0.02	0.16	0.65	> 0.65
11) Total dissolved solids (mg/L)	500	1500	5000	> 5000
12) Color (Pt-Co UNIT)	5	50	300	> 300
13) Sodium (mg Na^+/L)	125	125	250	> 250
B) Organic parameters				
1) Need for chemical oxygen (COD) (mg/L)	25	50	70	> 70
2) Need for biological oxygen (BOD) (mg/L)	4	8	20	> 20
3) Total organic carbon (mg/L)	5	8	12	> 12
4) Total kjeldahl-nitrogen (mg/L)	0.5	1.5	5	> 5
5) Oil and grease (mg/L)	0.02	0.3	0.5	> 0.5
6) Surface active material givin reaction with Metilen blue (MBAS) (mg/L)	0.05	0.2	1	> 1.5
7) PHENOLik materials (flier) (mg/L)	0.002	0.01	0.1	> 0.1
8) Mineral oils and types (mg/L)	0.02	0.1	0.5	> 0.5
9) Total pestisid (mg/L)	0.001	0.01	0.1	> 0.1
C) Inorganic pollution material				
1) Mercury (μg Hg/L)	0.1	0.5	2	> 2
2) CaDMIum (μg Cd/L)	3	5	10	> 10
3) Lead (μg Pb/L)	10	20	50	> 50
4) Arsenic (μg As/L)	20	50	100	> 100
5) Copper (μg Cu/L)	20	50	200	> 200
6) Chrome (total) (μg Cr/L)	20	50	200	> 200
7) Chrome(μg Cr^{+6}/L)	As less as not being measured	20	50	> 50
8) Cobalt (μg Co/L)	10	20	200	> 200
9) Nickel (μg Ni/L)	20	50	200	> 200
10) Zinc (μg Zn/L)	200	500	2000	> 2000
11) Cyanide (total) (μg CN/L)	10	50	100	> 100
12) Fluoride (μg F^-/L)	1000	1500	2000	> 2000
13) Free chlorine (μg Cl_2/L)	10	10	50	> 50
14) Sulphur (μg $S^=$/L)	2	2	10	> 10

Table A.1. Quality Criteria of Inland Water Resources (continued)

	WATER QUALITY CLASSES			
PARAMETER OF WATER QUALITY	I	II	III	IV
15) Ferrous (µg Fe/L)	300	1000	5000	> 5000
16) Manganese (µg Mn/L)	100	500	3000	> 3000
17) Boron (µg B/L)	1000[e]	1000[e]	1000[e]	> 1000
18) Selenium (µg Se/L)	10	10	20	> 20
19) Barium (µg Ba/L)	1000	2000	2000	> 2000
20) Aluminum (mg Al/L)	0.3	0.3	1	> 1
21) Radioactivity (pCi/L)				
Alpha -activity	1	10	10	> 10
Beta-activity	10	100	100	> 100
D) Bacteriological parameters				
1) Fecal coliform(EMS/100 mL)	10	200	2000	> 2000
2) Total coliform (EMS/100 mL)	100	20000	100000	> 100000

APPENDIX B

LIMITATION VALUES WITH EUTROPHICATION CONTROL OF LAKES, SMALL LAKES, BOGGIES, AND DAM BASINS

Table B.1. Limitation Values with Eutrophication Control of Lakes, Small Lakes, Boggies, and Dams (Regulation on Water Pollution Control; O.G. 31.12.2004 / 25687)

Required Features	**Usage Branches**	
	Natural Protection Area and recreation	**For various usages (with the natural salty, bitter and lakes)**
pH	6.5-8.5	6-10.5
COD (mg/L)	3	8
DO (mg/L)	7.5	5
SS (mg/L)	5	15
Total coliform number (EMS)/100 mL	1000	1000
Total nitrogen (mg/L)	0.1	1
Total phophorus (mg/L)	0.005	0.1
Chlorophyll -a (mg/L)	0.008	0.025

APPENDIX C

EU WATER STANDARDS GIVEN IN ANNEX I OF DIRECTIVE 80/778/EEC (LIST OF PARAMETERS)

Table C.1. EU Water Standards Given in Annex I of Directive 80/778/EEC

A. ORGANOLEPTIC PARAMETERS				
#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
1	Colour	mg/l Pt/Co scale	1	
2	Turbidity	mg/l SiO2 Jackson units	1 0.4	- Replaced in certain circumstances by a transparency test, with a Secchi disc reading in meters: GL: 6 m; MAC: 2 m
3	Odour	Dilution number	0	- To be related to the taste tests.
4	Taste	Dilution number	0	- To be related to the odour tests.
B. PHYSICO-CHEMICAL PARAMETERS (in relation to the water's natural structure)				
#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
5	Temperature	°C	12	25
6	Hydrogen ion concentration	pH unit	6.5< pH< 8.5	
7	Conductivity	(iS cm"^{1} at 20 °C	400	
8	Chlorides	Cl mg/l	25	
9	Sulphates	SO_4 mg/l	25	250
10	Silica	SiO_2 mg/l		
11	Calcium	Ca mg/l	100	
12	Magnesium	Mg mg/l	30	50
13	Sodium	Na mg/l	20	175 (as from 1984 and with a percentile of 90) 150 (as from 1987 and with a percentile of 80) (these percentiles should be calculated over a reference period of three years)
14	Potassium	K mg/l	10	12

Table C.1. EU Water Standards Given in Annex I of Directive 80/778/EEC (cont'd)

#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
15	Aluminium	Al mg/l	0.05	0.2
16	Total hardness	Table F of the Directive	Table F of the Directive	Table F of Annex I of the Directive
17	Dry residues		1 500	
18	Dissolved oxygen			- Saturation value > 75 % except for underground water.
19	Free carbon dioxide			Should not be aggressive.
C. PARAMETERS CONCERNING SUBSTANCES UNDESIRABLE IN EXCESSIVE AMOUNTS				
#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
20	Nitrates	NO_3 mg/l	25	50
21	Nitrites	NO_2 mg/l		0.1
22	Ammonium	NH_4 mg/l	0.05	0.5
23	Kjeldahl Nitrogen (excluding N in NO_2 and NO_3)	N mg/l		1
24	(K Mn O_4) Oxidizability	O_2 mg/l	2	5
25	Total organic carbon (TOC)	C mg/l		
26	Hydrogen sulphide	S µg/l		Undetectable organoleptically
27	Substances extractable in chloroform	mg/l dry residue	01	
28	Dissolved or emulsified hydrocarbons (after extraction by petroleum ether); Mineral oils	µg/l		10
29	Phenols (phenol index)	C6H5OH µg/l		0-5
30	Boron	B µg/l	1000	
31	Surfactants (reacting with methylene blue)	µg/l (lauryl sulphate)		200
32	Other organo-chlorine compounds not covered by parameters No 55	µg/l	1	
33	Iron	Fe µg/l	50	200
34	Manganese	Mn µg/l	20	50

Table C.1. EU Water Standards Given in Annex I of Directive 80/778/EEC (cont'd)

#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
35	Copper	Cu µg/l	100 - at outlets of pumping and/or treatment works and their substations 3000 - after the water has been standing for 12 hours in the piping and at the point where the water is made available to the consumer	
#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
36	Zinc	Zn µg/l	100 - at outlets of pumping and/or treatment works	- Above 5 000µg/l a stringent taste, opalescence and sand-like deposits may occur.
37	Phosphorus	P_2O_5 µg/l	400	5 000
38	Fluoride	F µg/l 8 – 12 °C 25 - 30 °C		 1 500 700
39	Cobalt	Co ng/1		
40	Suspended solids		None	
41	Residual Chlorine	Cl µg/l		
42	Barium	Ba µg/l	100	
43	Silver	Ag µg/l		10
D. PARAMETERS CONCERNING TOXIC SUBSTANCES				
#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
44	Arsenic	As µg/l		50
45	Beryllium	Be µg/l		
46	CaDMIum	Cd µg/l		5
47	Cyanides	CN µg/l		50
48	Chromium	Cr µg/l		50
49	Mercury	Hg µg/l		1
50	Nickel	Ni µg/l		50

Table C.1. EU Water Standards Given in Annex I of Directive 80/778/EEC (cont'd)

#	*Parameters*	*Expression of the results*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
51	Lead	Pb µg/l		50 (in running water)
52	Antimony	Sb µg/l		10
53	Selenium	Se µg/l		10
54	Vanadium	V µg/l		
55	Pesticides and related products - substances considered separately - total	µg/l	 0.1 0.5	01 0-5
56	Polycyclic aromatic hydro carbons			0.2

E. MICROBIOLOGICAL PARAMETERS

#	*Parameters*	*Results: volume of the sample in ml*	*Guide level (GL)*	*Max. Adm. Conc. (MAC)*	
				Me. Fil. M.	MPN
57	Total coliforms	100	—	0	MPN < 1
58	Fecal coliforms	100	—	0	MPN < 1
59	Fecal streptococi	100	—	0	MPN < 1
60	Sulphite reducing Clostridia	20			MPN < 1

#	*Parameters*	*T (℃)*	*Results: size of sample (in ml)*	*Guide Level (GL)*	*Maximum admissible concentration (MAC)*
61	Total bacteria counts for water supplied for human consumption	37	1	10	—
		22	1	100	—
62	Total bacteria counts for water in closed containers	37	1	5	20
		22	1	20	100

APPENDIX D

EU WATER STANDARDS GIVEN IN WATER FRAMEWORK DIRECTIVE (2000/60/EC)

Table D.1. Normative Definitions of Ecological Status Classification

Element	**High status**	**Good status**	**Moderate status**
General	There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydro-morphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion. These are the type-specific conditions and communities.	The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.	The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.

Table D.1. Normative Definitions of Ecological Status Classification (continued)

Definitions for high, good and moderate ecological status in rivers (Physico-chemical quality elements)			
General conditions	The values of the physico-chemical elements correspond totally or nearly totally to undisturbed conditions. Nutrient concentrations remain within the range normally associated with undisturbed conditions. Levels of salinity, pH, oxygen balance, acid neutralizing capacity and temperature do not show signs of anthropogenic disturbance and remain within the range normally associated with undisturbed conditions.	Temperature, oxygen balance, pH, acid neutralizing capacity and salinity do not reach levels outside the range established so as to ensure the functioning of the type specific ecosystem and the achievement of the values specified above for the biological quality elements. Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific Synthetic pollutants	Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific non-synthetic pollutants	Concentrations remain within the range normally associated with undisturbed conditions (background levels = bgl).	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements.

Table D.1. Normative Definitions of Ecological Status Classification (continued)

Definitions for high, good and moderate ecological status in lakes (Physico-chemical quality elements)			
Element	**High status**	**Good status**	**Moderate status**
General conditions	The values of the physico-chemical elements correspond totally or nearly totally to undisturbed conditions. Nutrient concentrations remain within the range normally associated with undisturbed conditions. Levels of salinity, pH, oxygen balance, acid neutralising capacity and temperature do not show signs of anthropogenic disturbance and remain within the range normally associated with undisturbed conditions.	Temperature, oxygen balance, pH, acid neutralising capacity and salinity do not reach levels outside the range established so as to ensure the functioning of the type specific ecosystem and the achievement of the values specified above for the biological quality elements. Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific Synthetic pollutants	Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific non-synthetic pollutants	Concentrations remain within the range normally associated with undisturbed conditions (background levels - bgl).	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements.

APPENDIX E

LIMIT VALUES, PUBLIC INFORMATION AND ALERT THRESHOLDS GIVEN IN ANNEX-I OF THE REGULATION ON AIR QUALITY ASSESSMENT AND MANAGEMENT

Table E.1. Limit Values, Public Information and Alert Thresholds (The Regulation on Air Quality Assessment and Management)

Pollutant	**SULPHUR DIOXIDE**			**PARTICULATE MATTER**	
Averaging period	**1 hour** Hourly limit value for the protection of human health	**24 hours** Daily limit value for the protection of human health	**Calendar year and winter** (1 October to 31 March) Limit value for the protection of ecosystems	**24 hours** Limit value for the protection of human health	**Calendar year** Limit value for the protection of human health
Limit value	**350 µg/m³** not to be exceeded more than 24 times a calendar year	**125 µg/m³** Not to be exceeded more than 3 times a calendar year	**20 µg/m³**	**50 µg/m³** Not to be exceeded more than 35 times a calendar year	**40 µg/m³**
Margin of tolerance	**150 µg/m³** (43 %) On 1 January 2014 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2019	**125 µg/m³** (100 %) On 1 January 2014 and every 12 months thereafter by equal annual percentagesto reach 0% by 1 January 2019		**50 µg/m³** (100 %) on 1 January 2014 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2019	**20 µg/m³** (40 %) on 1 January 2014 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2019

Table E.1. Limit Values, Public Information and Alert Thresholds (continued)

Pollutant	SULPHUR DIOXIDE			PARTICULATE MATTER	
Upper assessment threshold		60% of 24-hour limit value (**75 µg/m³**, not to be exceeded more than 3 times in any calendar year)	60% of winter limit value (**12 µg/m³**)	**30 µg/m³**, (not to be exceeded more than 7 times in any calendar year)	**14 µg/m³**
Lower assessment threshold		40% of 24-hour limit value (**50 µg/m³**, not to be exceeded more than 3 times in any calendar year)	40% of winter limit value (**8 µg/m³**)	**20 µg/m³**, (not to be exceeded more than 7 times in any calendar year)	**10 µg/m³**
Date by which limit value is set to be met	1 January 2019	1 January 2019	1 January 2014	1 January 2019	1 January 2019
Alert threshold	**500 µg/m³** measured over three consecutive hours at locations representative of air quality over at least 100 km² or an entire zone or agglomeration, whichever is the smaller.			----	

APPENDIX F

LIMIT VALUES AND THE ALERT THRESHOLD VALUES FOR SULPHUR DIOXIDE, AND PARTICULATE MATTER GIVEN IN COUNCIL DIRECTIVE 96/62/EC ON AMBIENT AIR QUALITY ASSESSMENT AND MANAGEMENT

Table F.1. Limit Values and the Alert Threshold Values for Sulphur Dioxide, and Particulate Matter (Council Directive 96/62/EC on Ambient Air Quality Assessment and Management)

Pollutant	**SULPHUR DIOXIDE**			**PARTICULATE MATTER**	
Averaging period	**1 hour** Hourly limit value for the protection of human health	**24 hours** Daily limit value for the protection of human health	**Calendar year and winter** (1 October to 31 March) Limit value for the protection of ecosystems	**24 hours** Limit value for the protection of human health	**Calendar year** Limit value for the protection of human health
Limit value	**350 µg/m^3** not to be exceeded more than 24 times a calendar year	**125 µg/m^3** Not to be exceeded more than 3 times a calendar year	**20 µg/m^3**	**50 µg/m^3** Not to be exceeded more than 35 times a calendar year	**40 µg/m^3**
Margin of tolerance	**150 µg/m^3** (43 %) On 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	**None**	None	**50 %** on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	**20 %** on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005

Table F.1. Limit Values and the Alert Threshold Values for Sulphur Dioxide, and Particulate Matter (continued)

Pollutant	**SULPHUR DIOXIDE**			**PARTICULATE MATTER**	
Upper assessment threshold		60% of 24-hour limit value (**75 µg/m^3**, not to be exceeded more than 3 times in any calendar year)	60% of winter limit value (**12 µg/m^3**)	---	---
Lower assessment threshold		40% of 24-hour limit value (**50 µg/m^3**, not to be exceeded more than 3 times in any calendar year)	40% of winter limit value (**8 µg/m^3**)	---	---
Date by which limit value is set to be met	1 January 2005	1 January 2005	1 January 2001	1 January 2005	1 January 2005
Alert threshold	**500 µg/m^3** measured over three consecutive hours at locations representative of air quality over at least 100 km^2 or an entire zone or agglomeration, whichever is the smaller.			----	

APPENDIX G

THE PRODUCED RESULTS OF SELECTED AIR QUALITY VARIABLES PRODUCED BY DIFFERENT INTERPOLATION METHODS

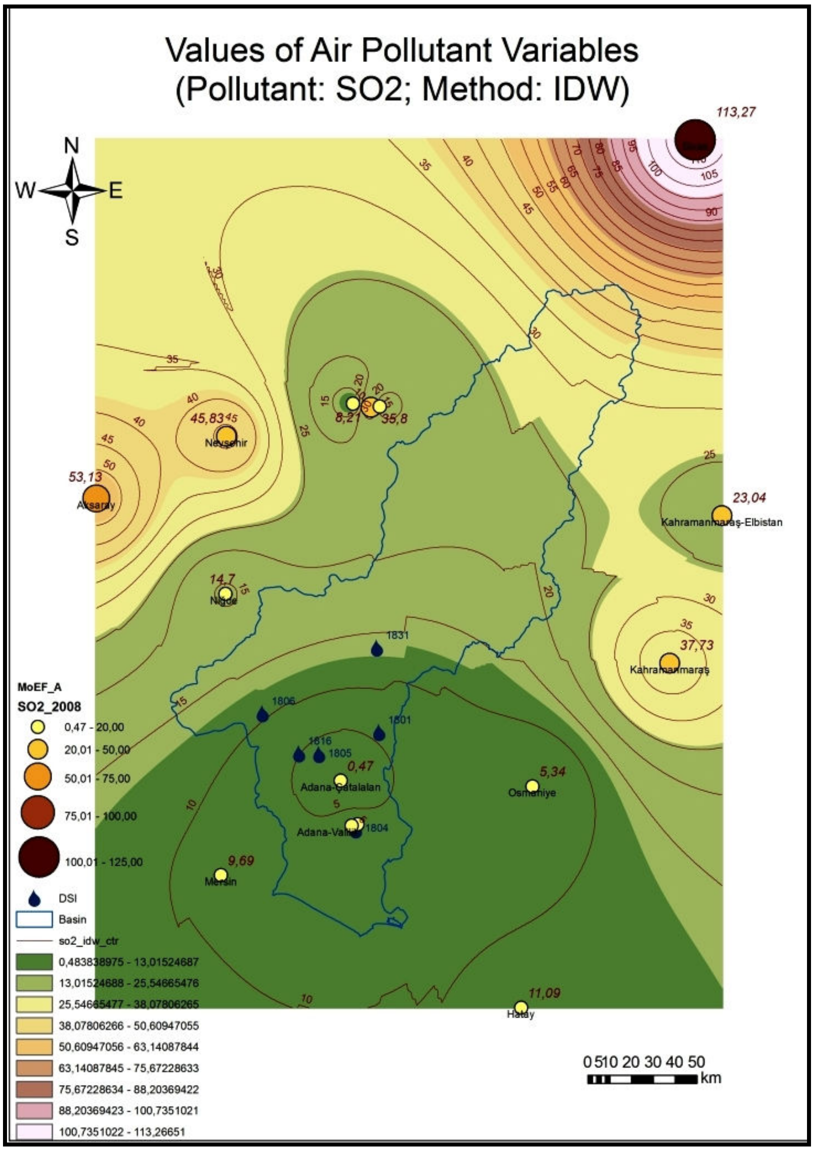

Figure G.1. The Produced Results of SO_2 Produced by IDW Interpolation Method

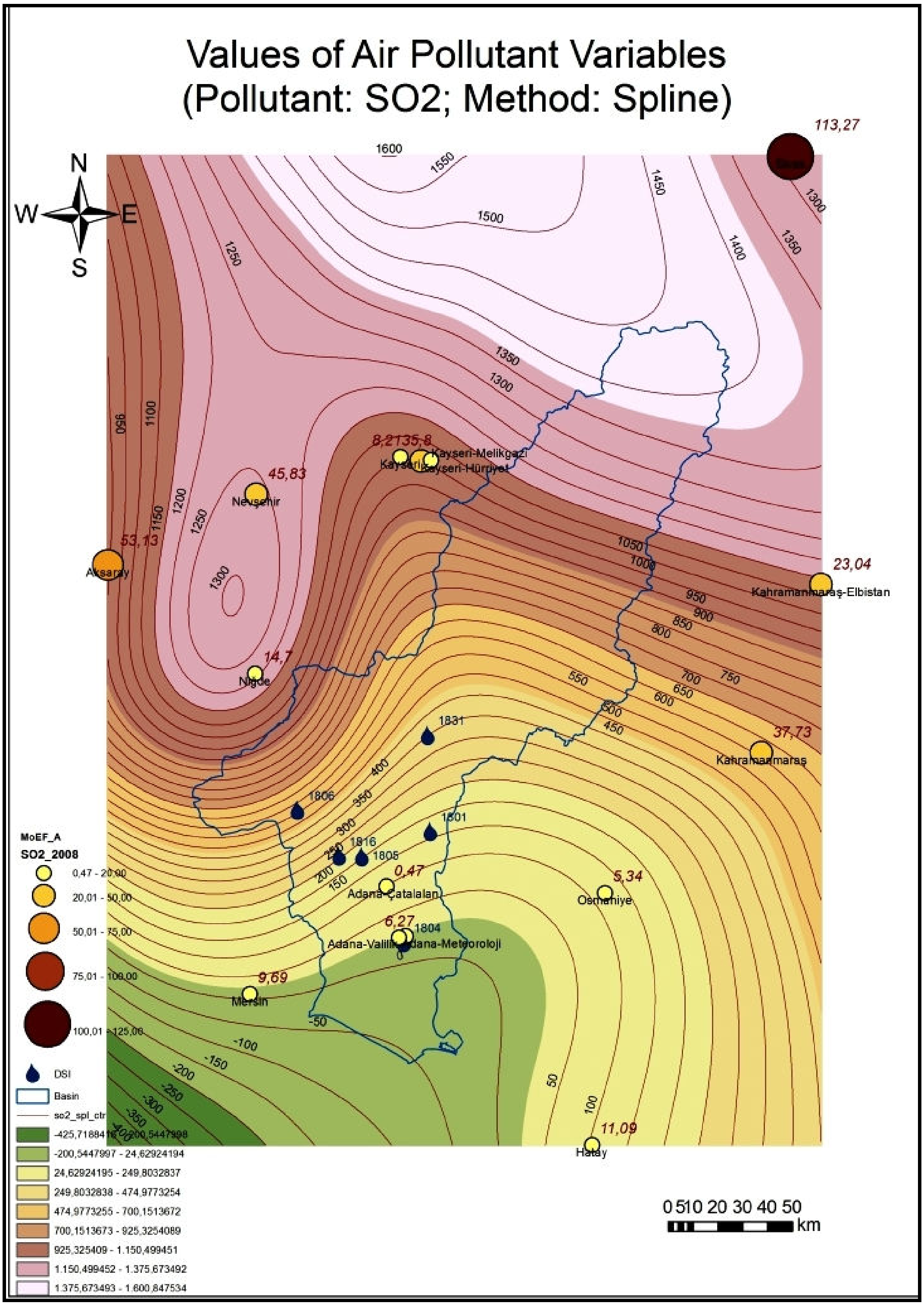

Figure G.2. The Produced Results of SO_2 Produced by Spline Interpolation Method

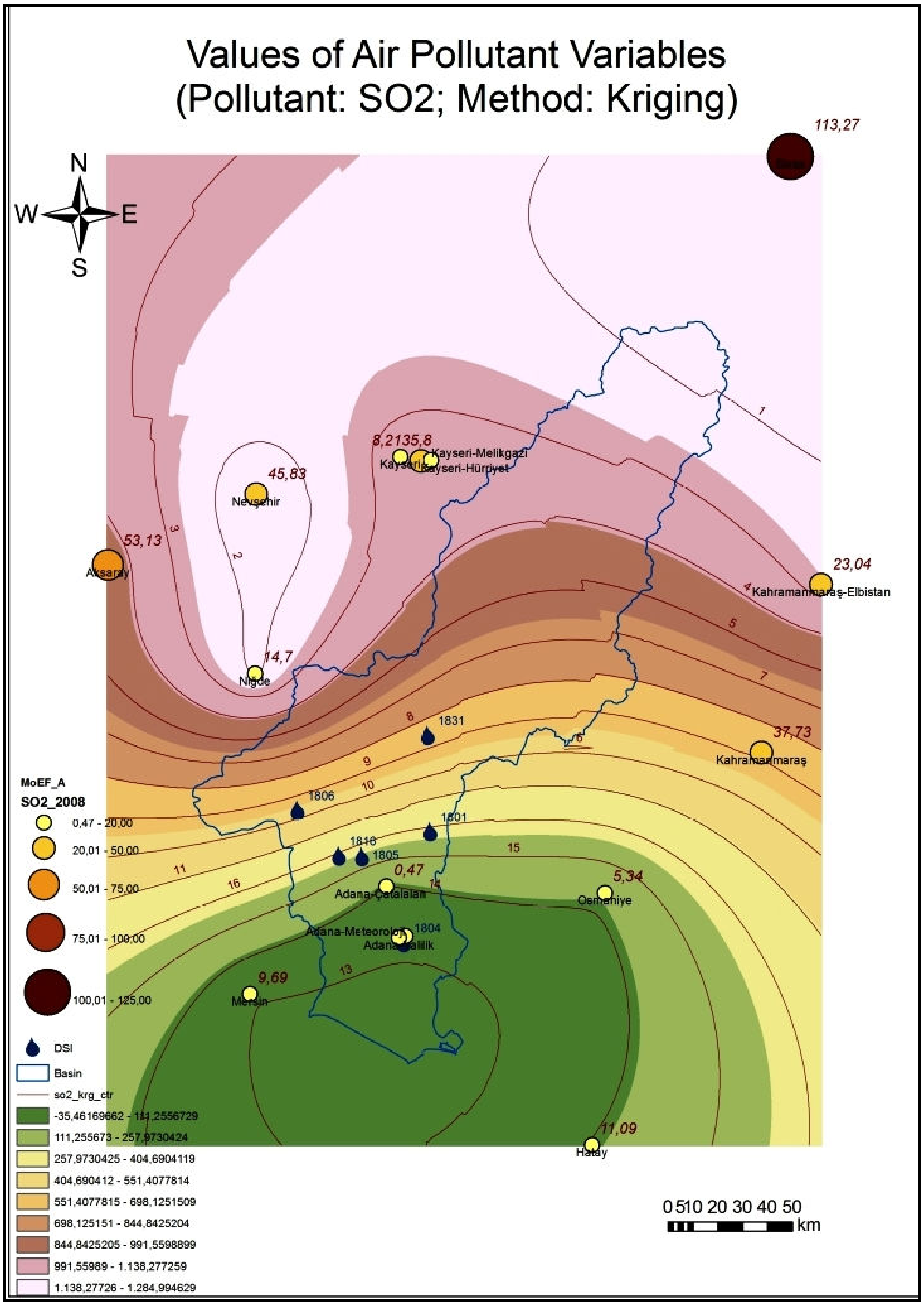

Figure G.3. The Produced Results of SO_2 Produced by Kriging Interpolation Method

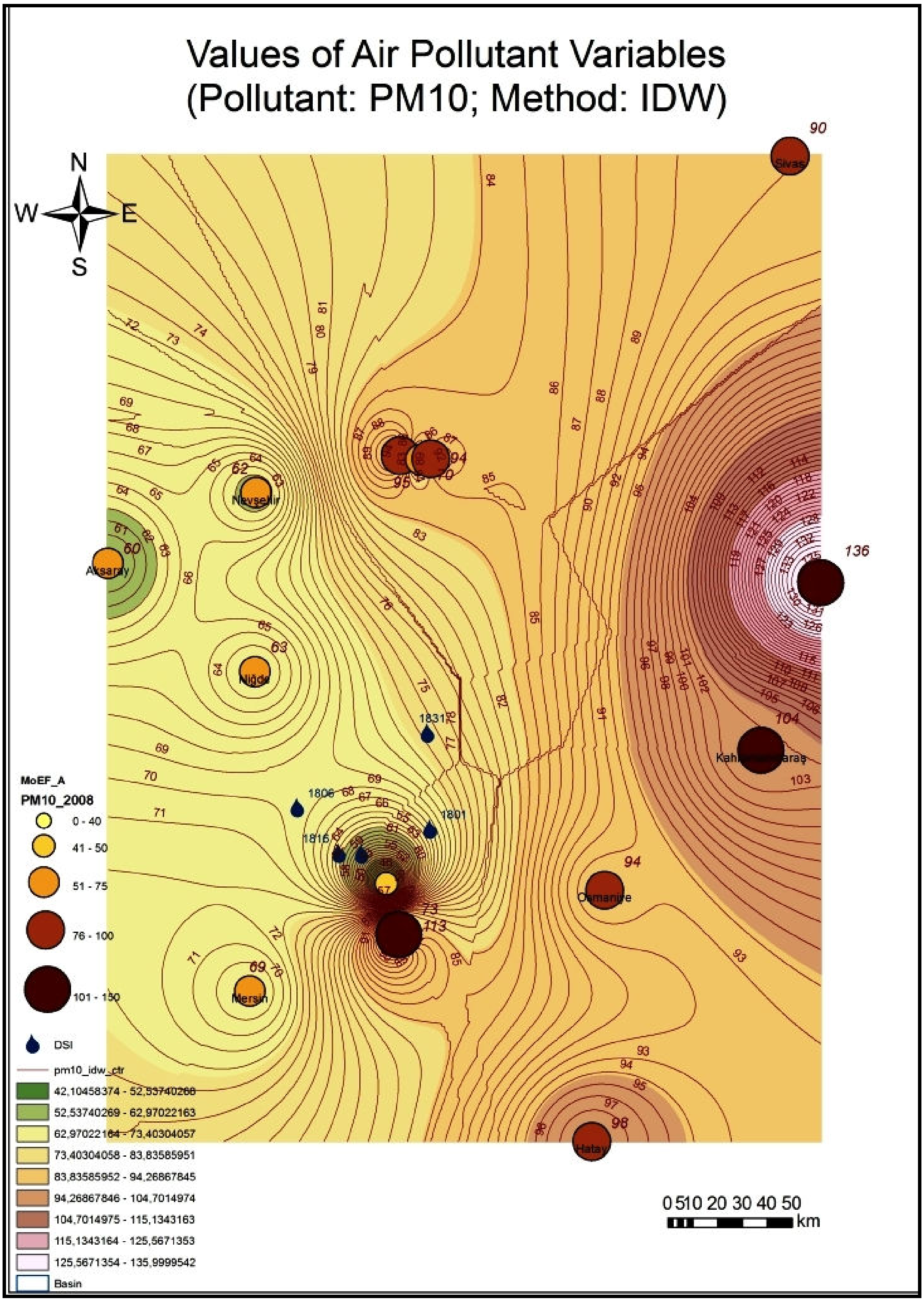

Figure G.4. The Produced Results of PM_{10} Produced by IDW Interpolation Method

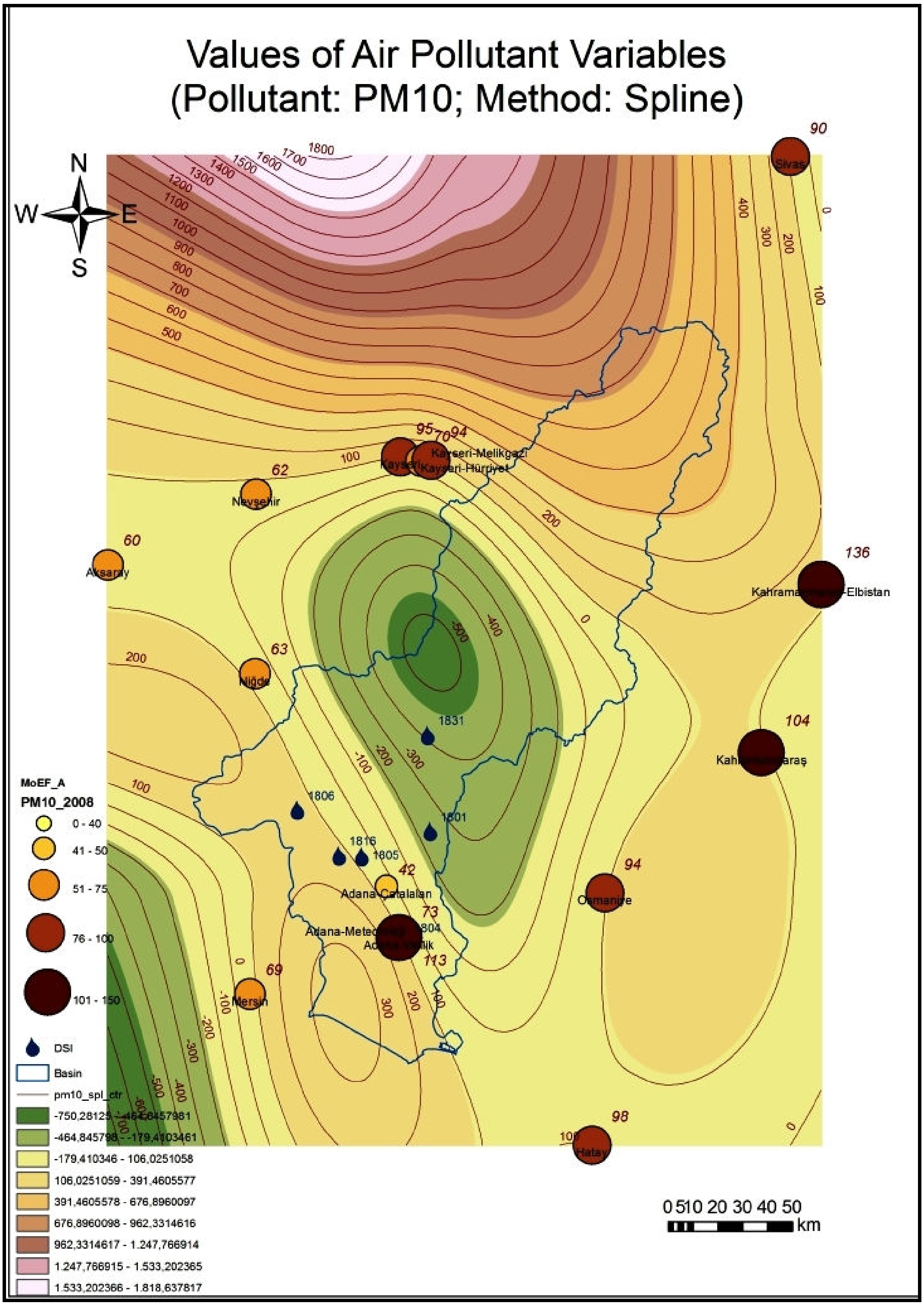

Figure G.5. The Produced Results of PM_{10} Produced by Spline Interpolation Method

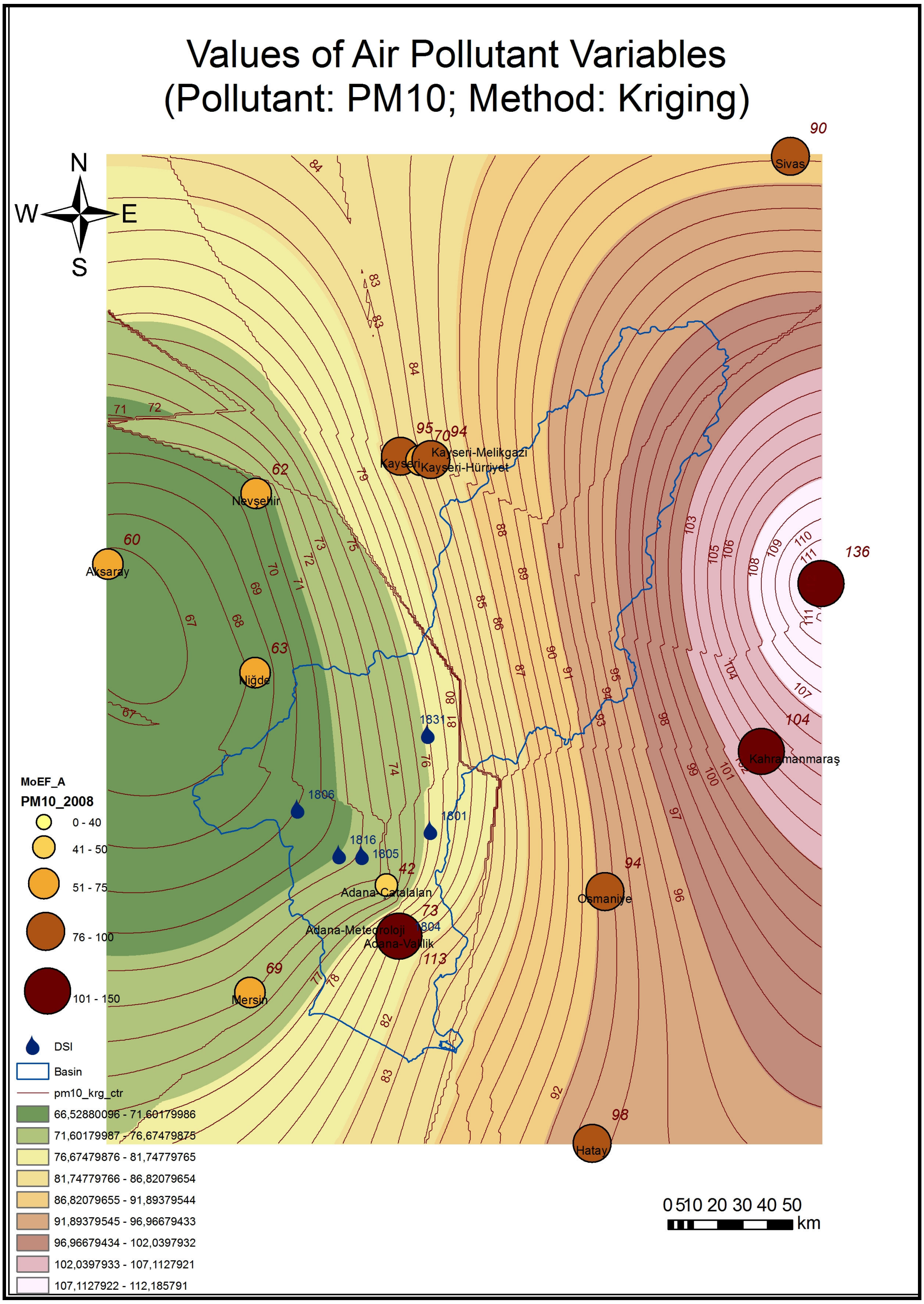

Figure G.6. The Produced Results of PM_{10} Produced by Kriging Interpolation Method

APPENDIX H

CONCENTRATIONS AND VALUES OF SELECTED WATER QUALITY PARAMETERS

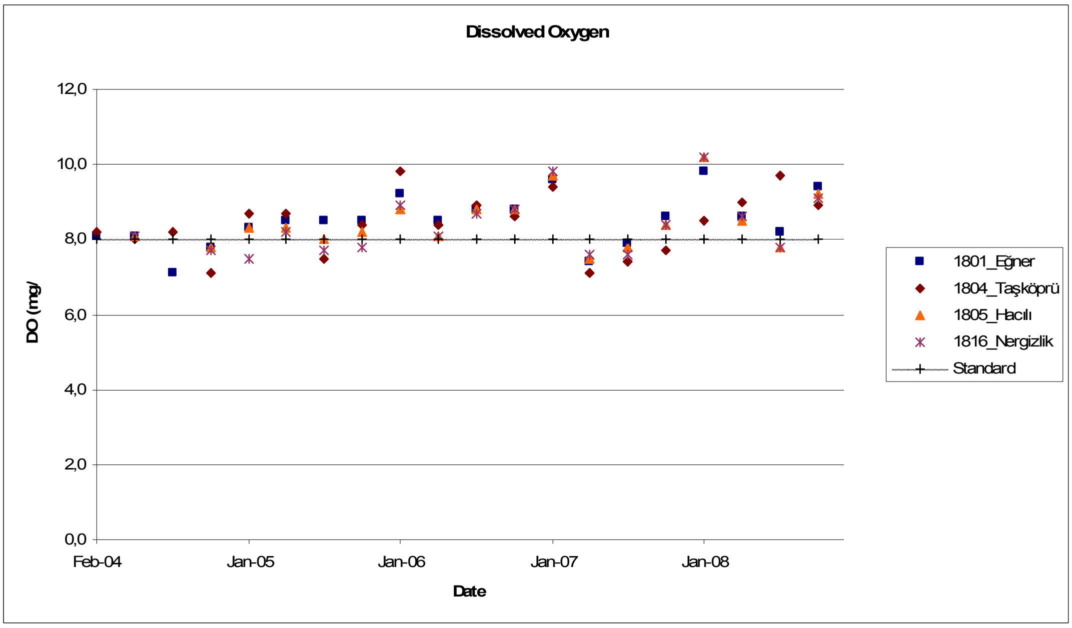

Figure H.1. Concentration of DO for 2004-2008

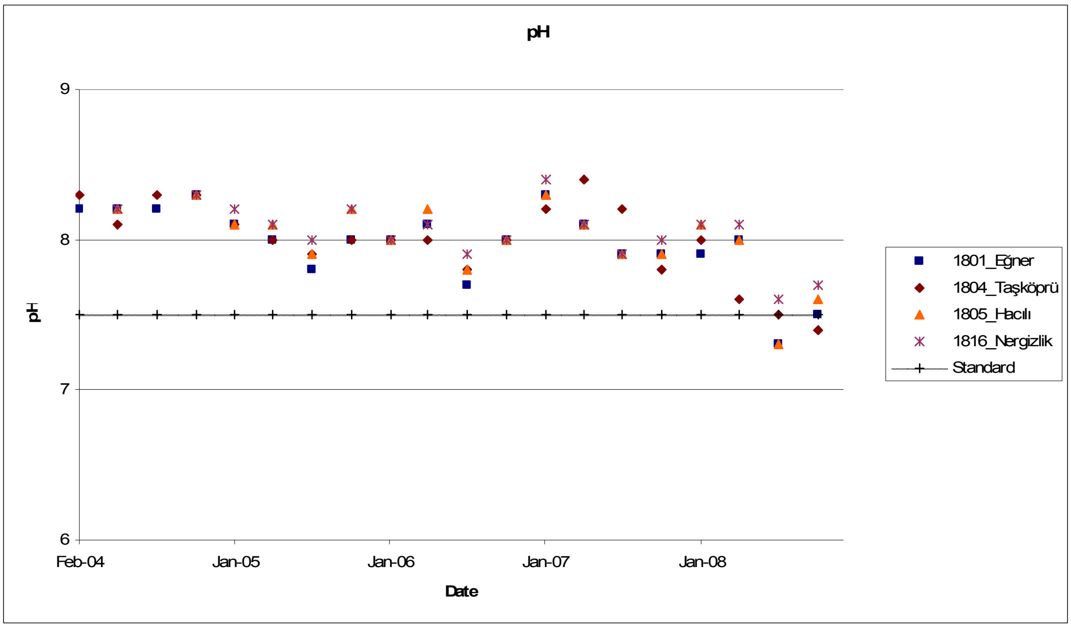

Figure H.2. pH for 2004-2008

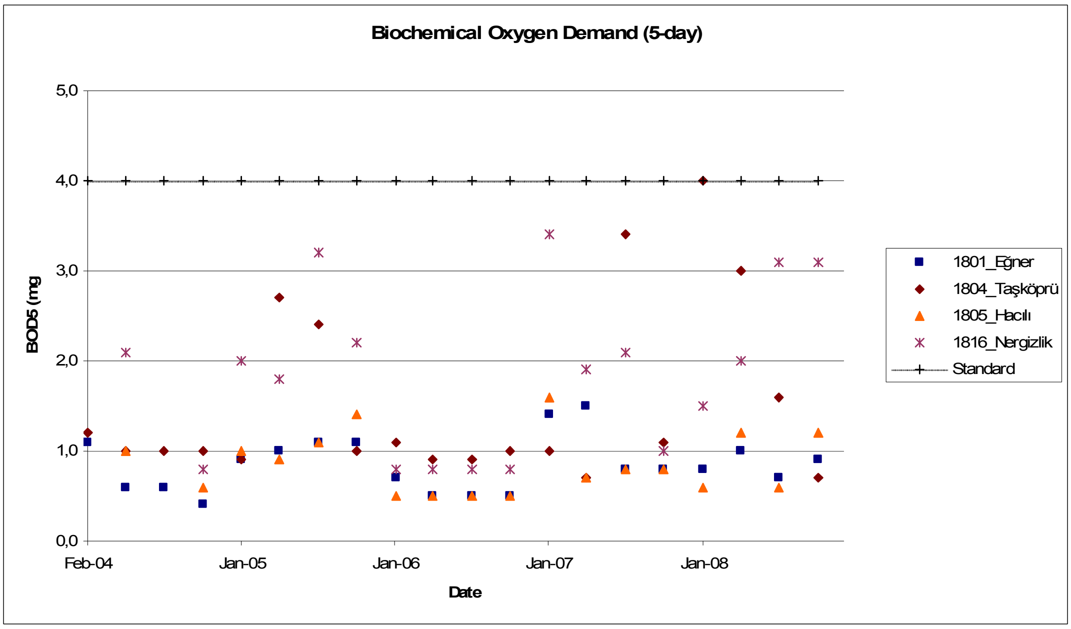

Figure H.3. Concentration of BOD_5 for 2004-2008

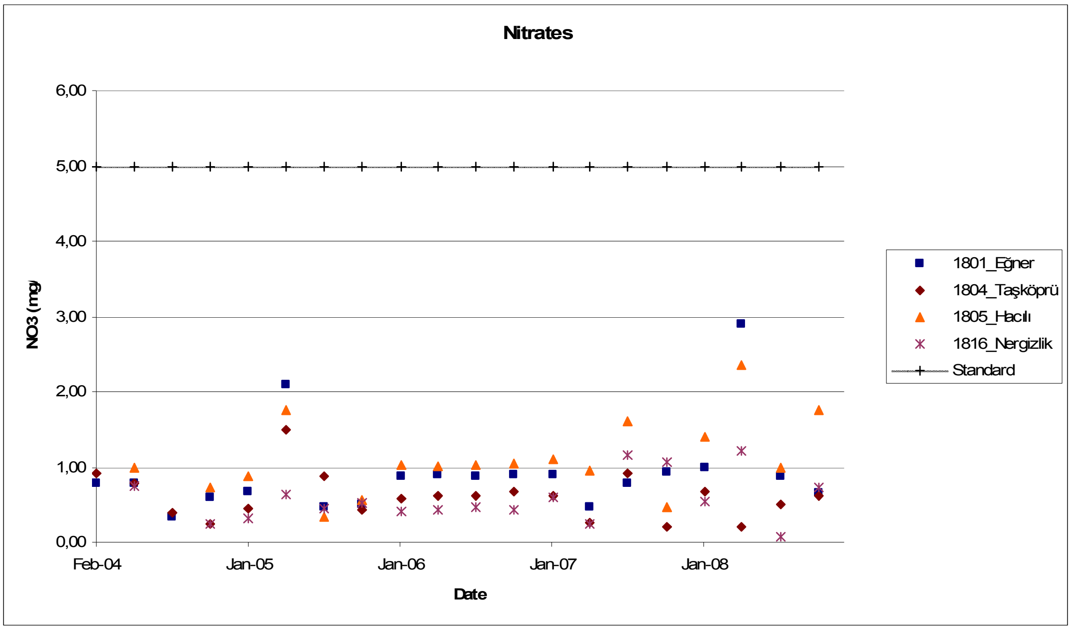

Figure H.4. Concentration of NO_3 for 2004-2008

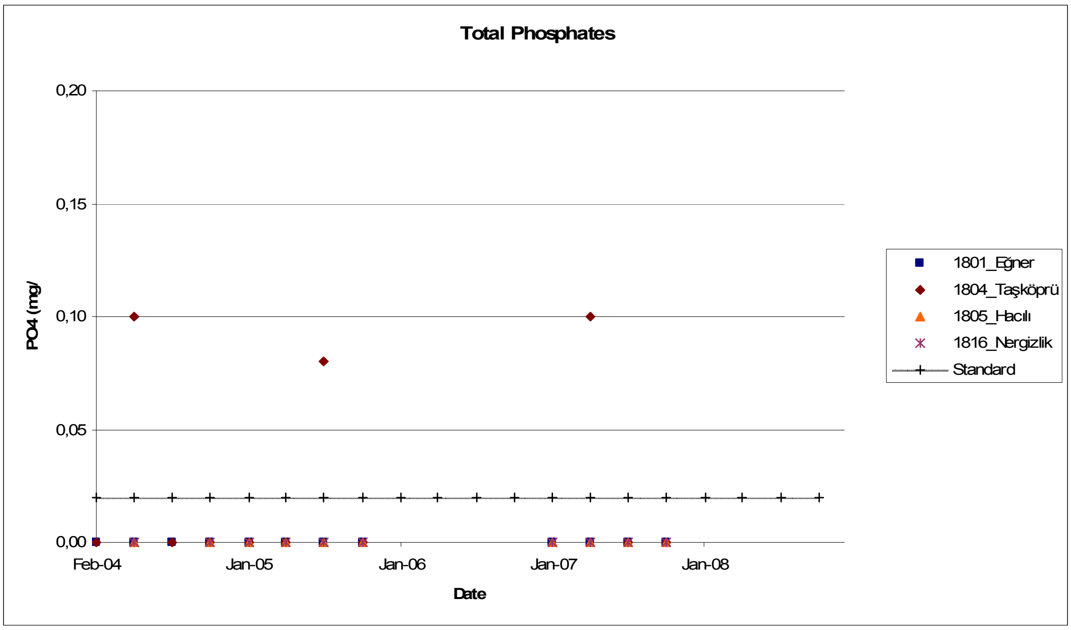

Figure H.5. Concentration of PO_4 for 2004-2008

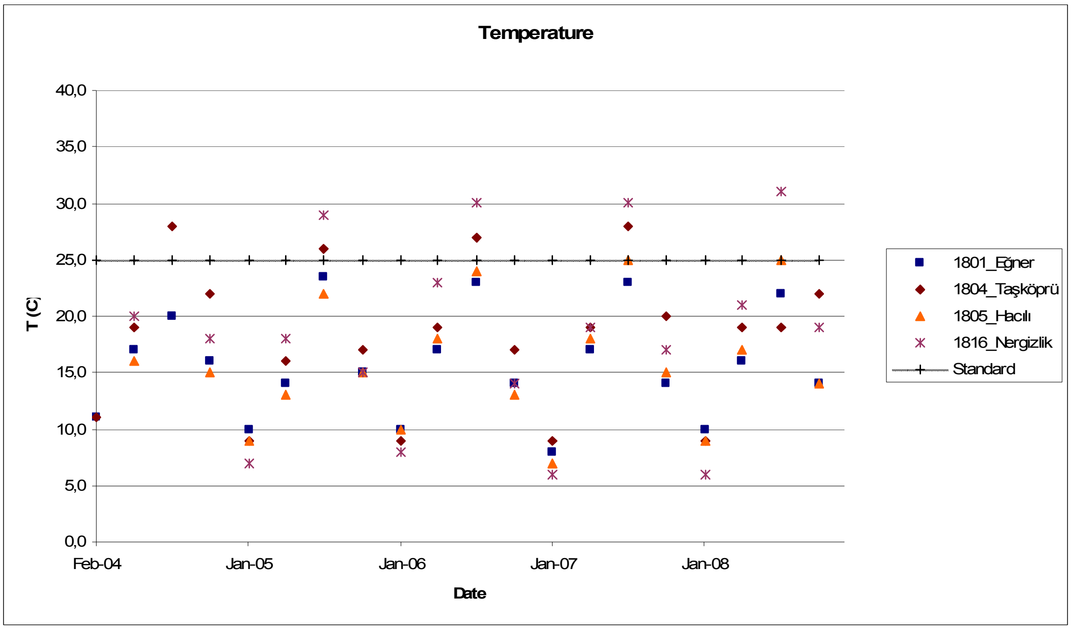

Figure H.6. T for 2004-2008

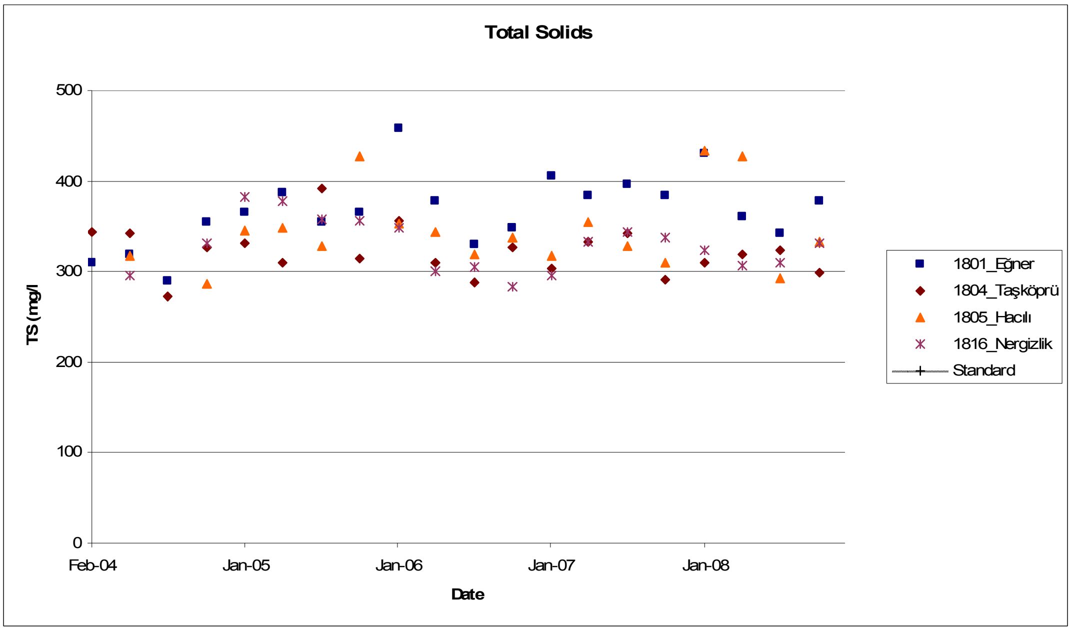

Figure H.7. Concentration of TS for 2004-2008

APPENDIX I

MEASURED SO_2 CONCENTRATIONS OF SELECTED AIR MONITORING STATIONS

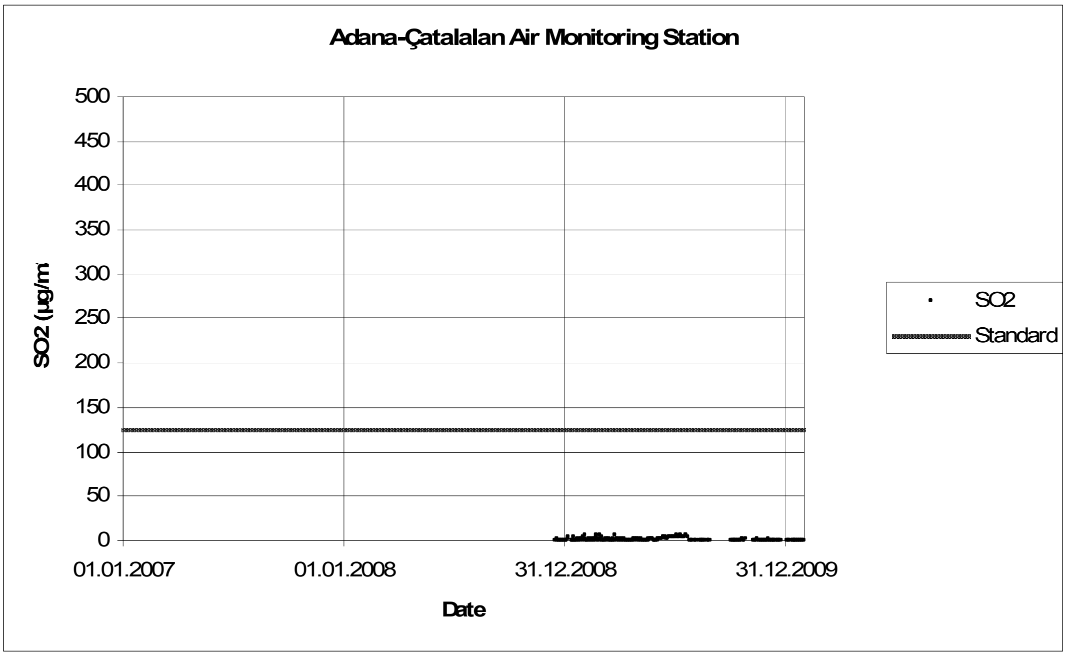

Figure I.1. Measured Daily SO_2 Concentration Measured at Adana-Çatalalan Air Monitoring Station

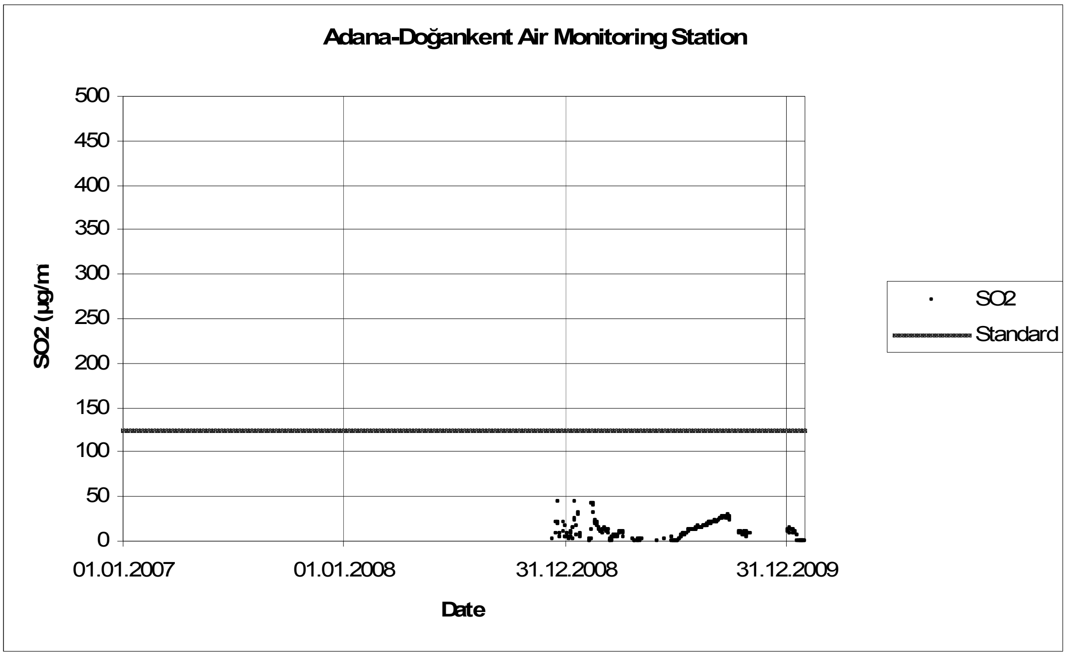

Figure I.2. Measured Daily SO_2 Concentration Measured at Adana-Doğankent Air Monitoring Station

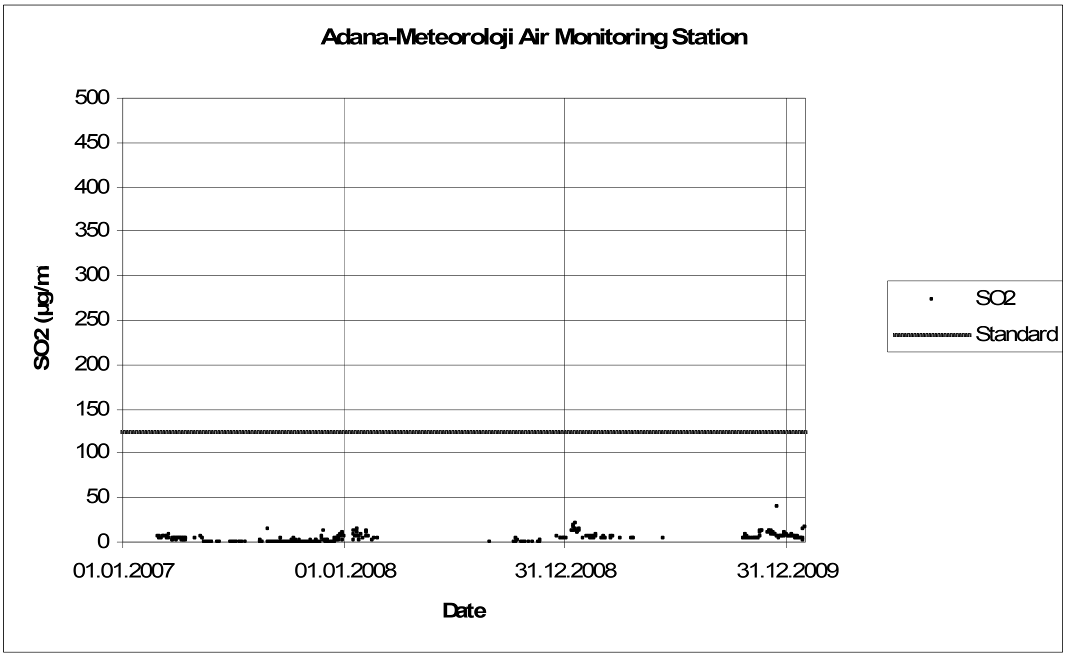

Figure I.3. Measured Daily SO_2 Concentration Measured at Adana-Meteoroloji Air Monitoring Station

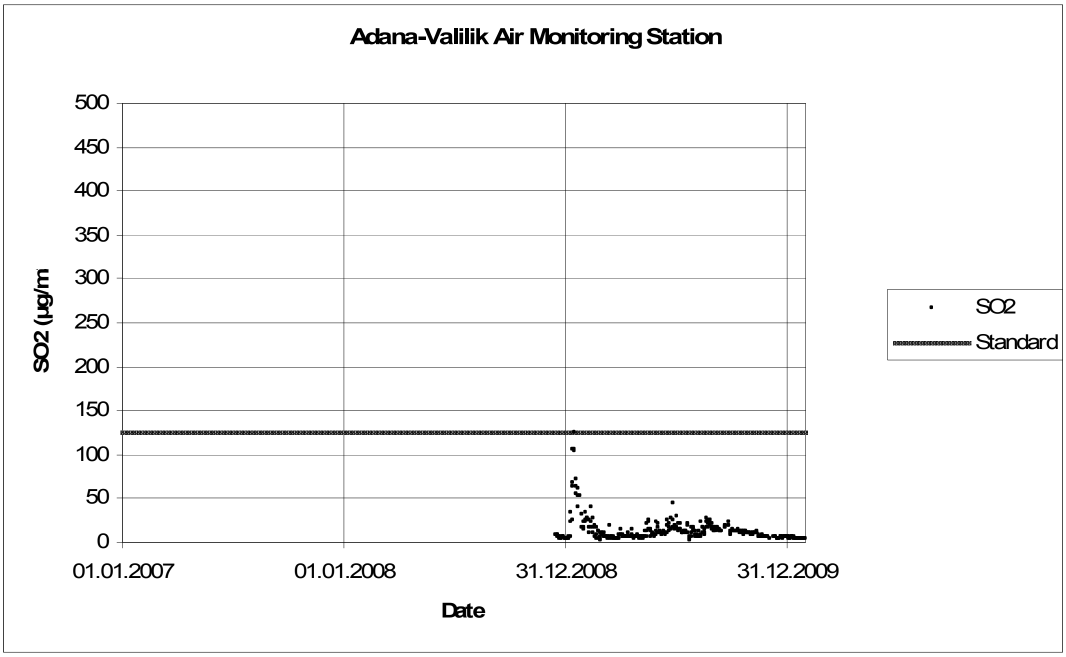

Figure I.4. Measured Daily SO_2 Concentration Measured at Adana-Valilik Air Monitoring Station

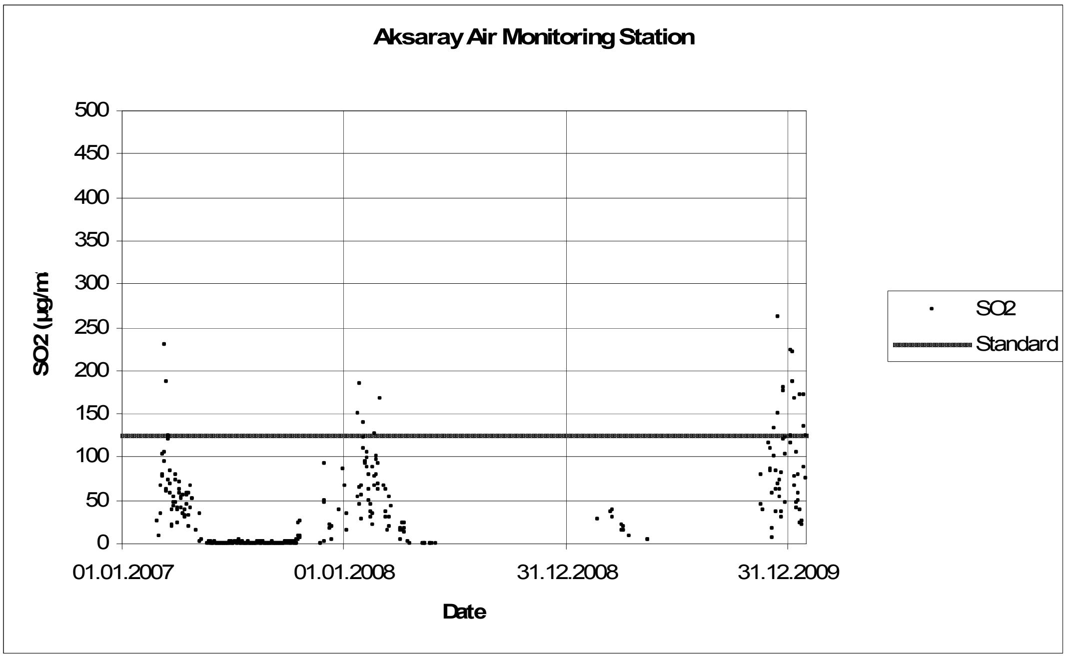

Figure I.5. Measured Daily SO_2 Concentration Measured at Aksaray Air Monitoring Station

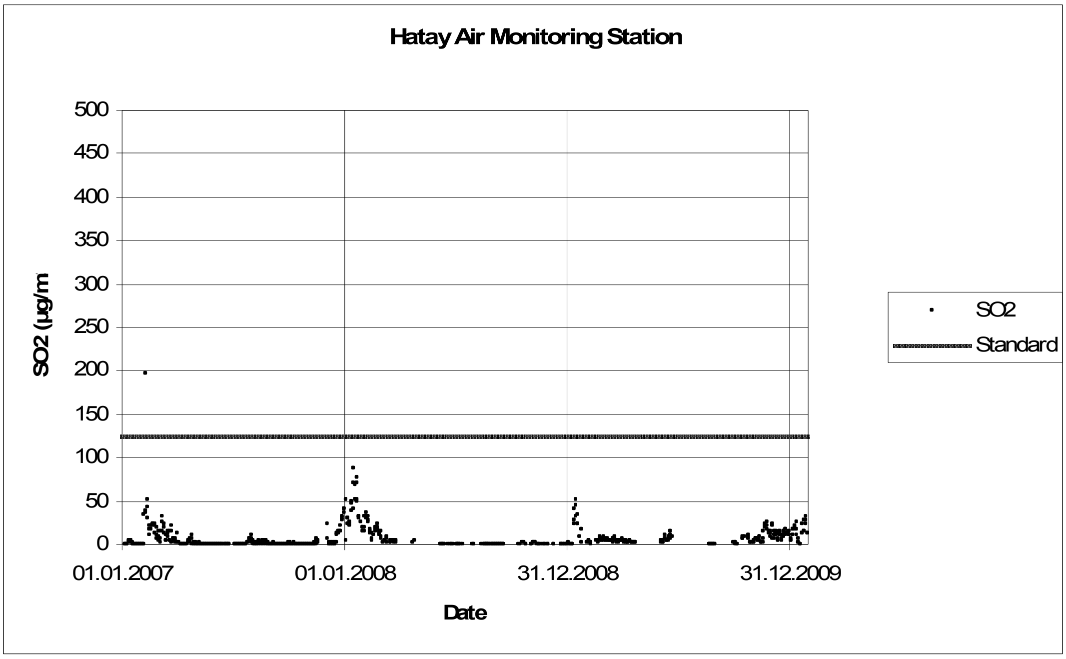

Figure I.6. Measured Daily SO_2 Concentration Measured at Hatay Air Monitoring Station

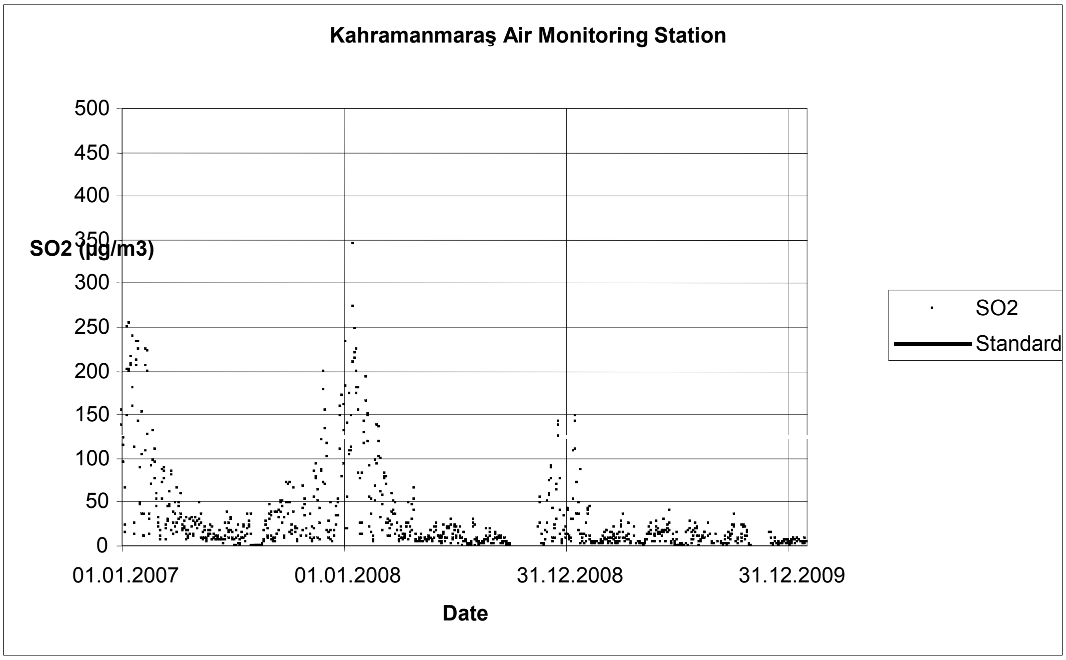

Figure I.7. Measured Daily SO_2 Concentration Measured at Kahramanmaraş Air Monitoring Station

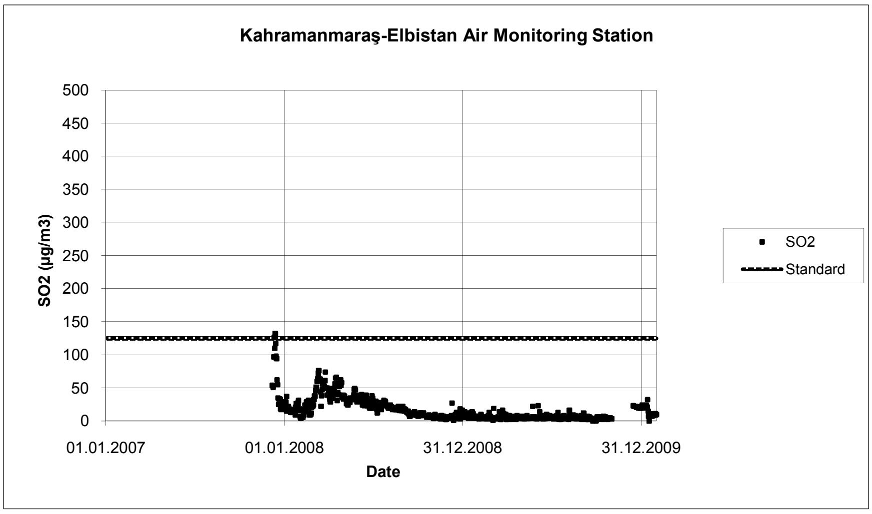

Figure I.8. Measured Daily SO2 Concentration Measured at Kahramanmaraş-Elbistan Air Monitoring Station

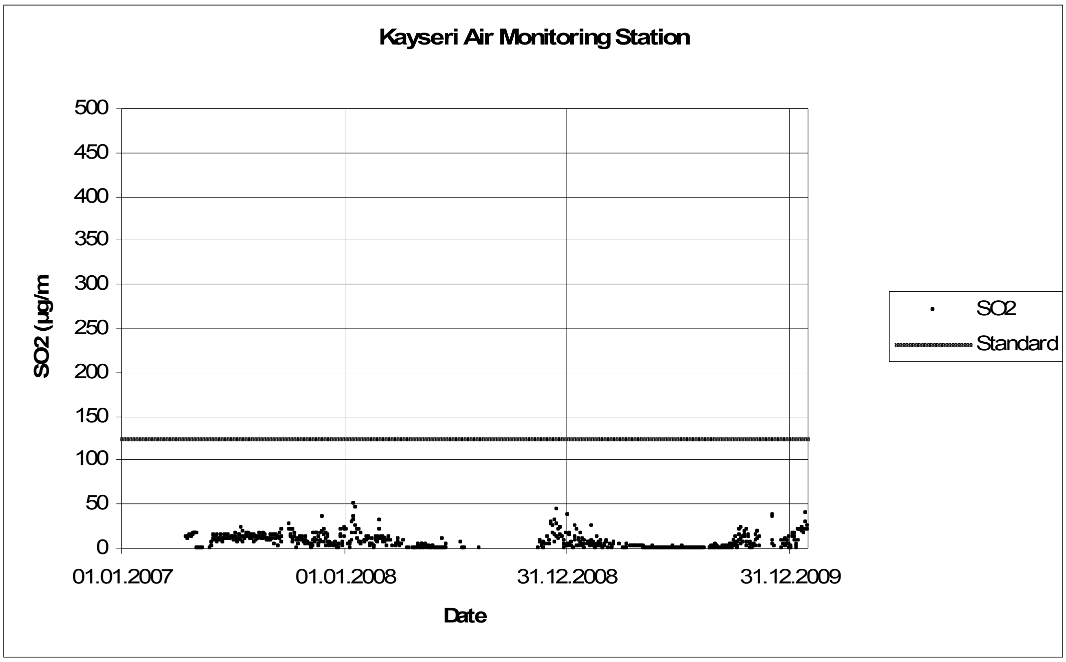

Figure I.9. Measured Daily SO_2 Concentration Measured at Kayseri Air Monitoring Station

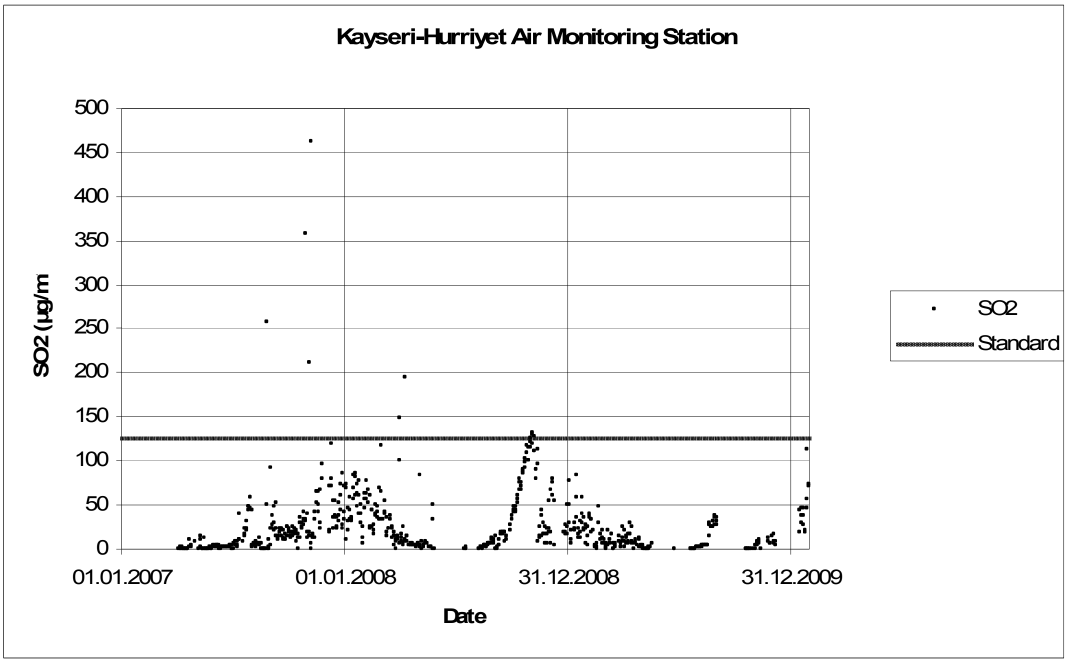

Figure I.10. Measured Daily SO_2 Concentration Measured at Kayseri-Hürriyet Air Monitoring Station

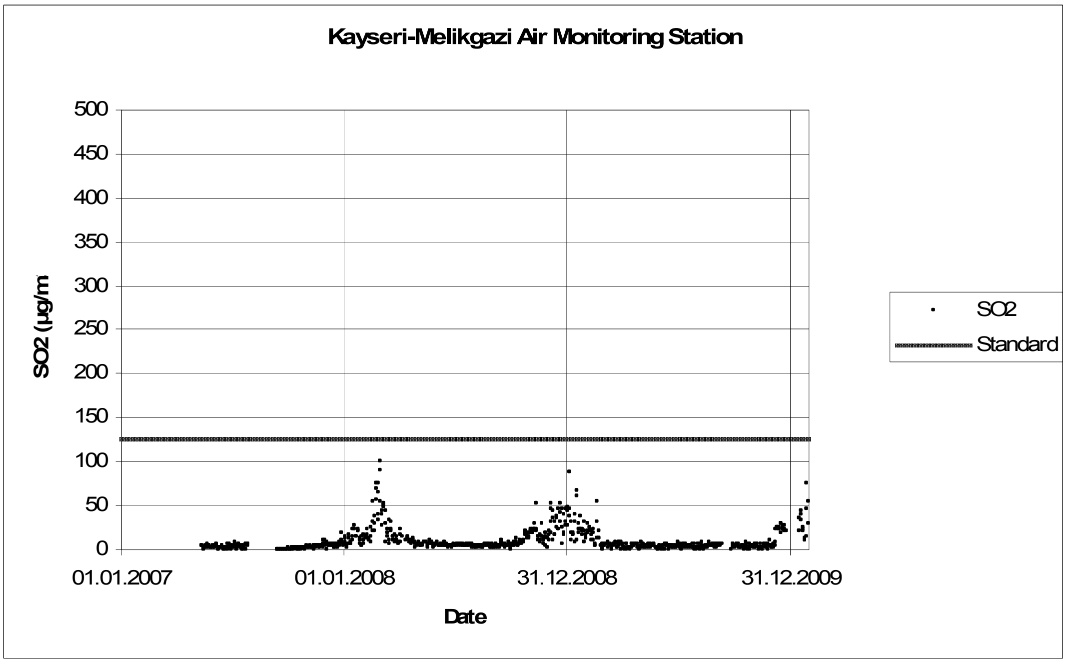

Figure I.11. Measured Daily SO_2 Concentration Measured at Kayseri-Melikgazi Air Monitoring Station

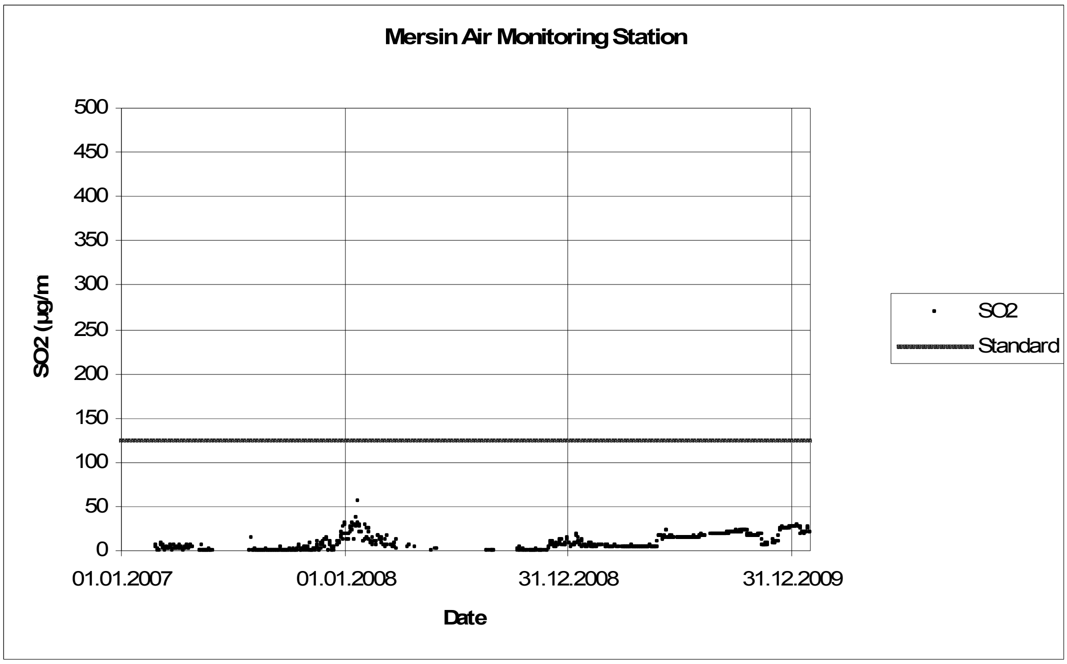

Figure I.12. Measured Daily SO_2 Concentration Measured at Mersin Air Monitoring Station

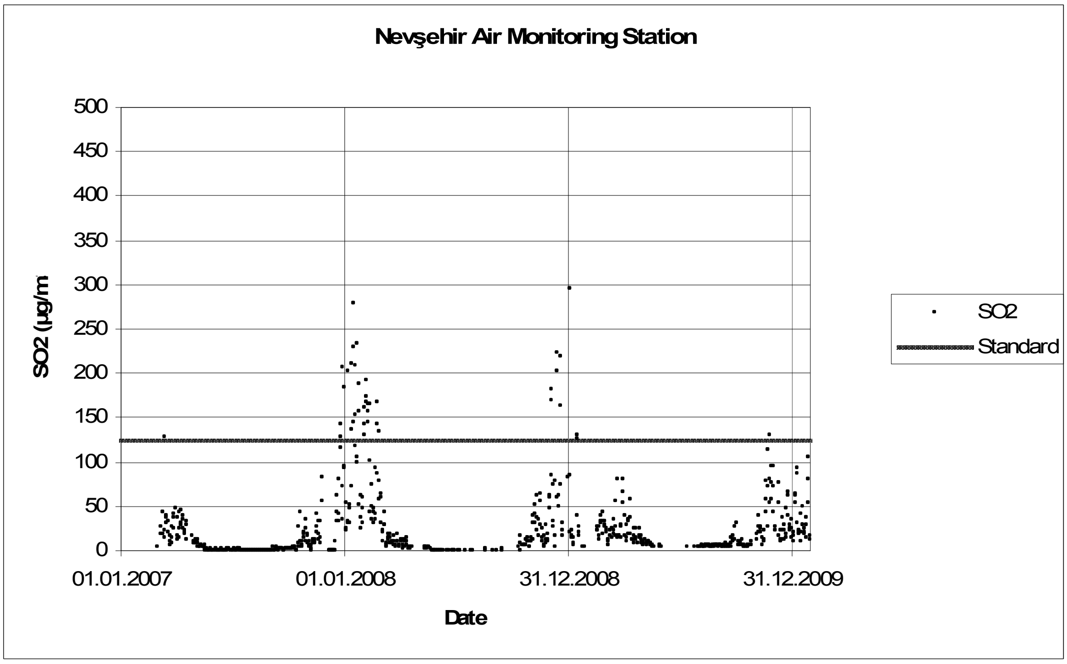

Figure I.13. Measured Daily SO_2 Concentration Measured at Nevşehir Air Monitoring Station

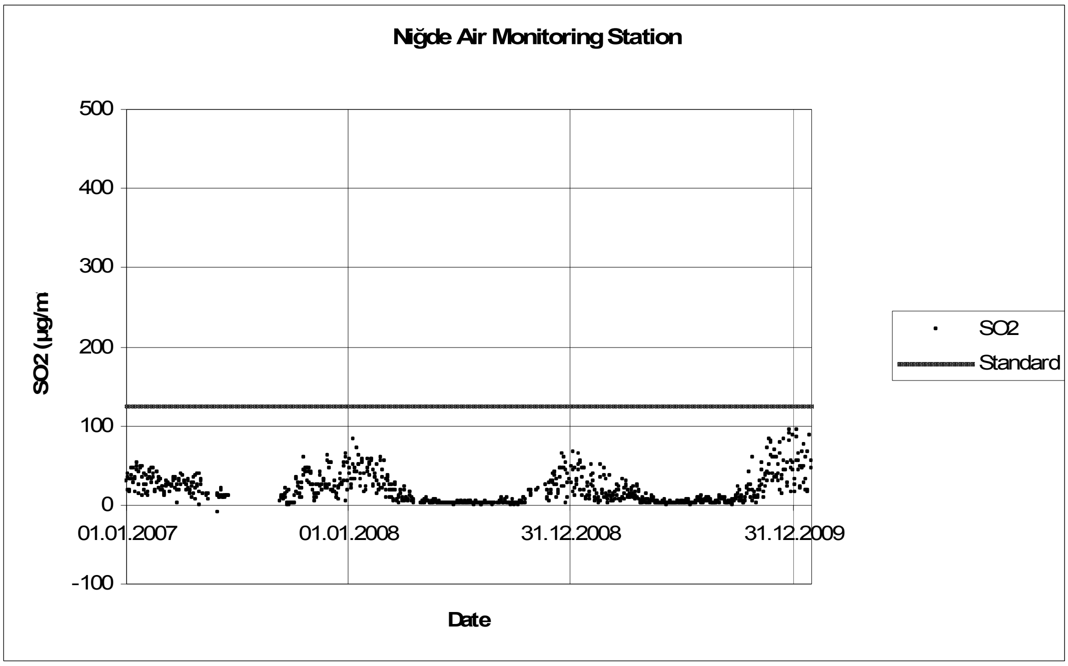

Figure I.14. Measured Daily SO_2 Concentration Measured at Niğde Air Monitoring Station

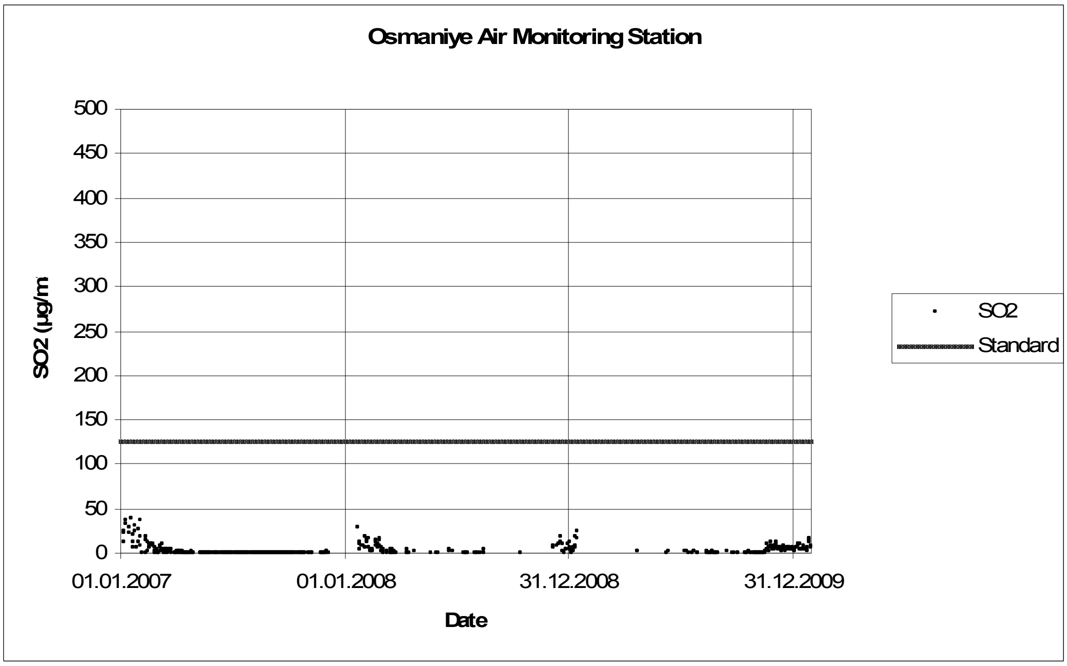

Figure I.15. Measured Daily SO_2 Concentration Measured at Osmaniye Air Monitoring Station

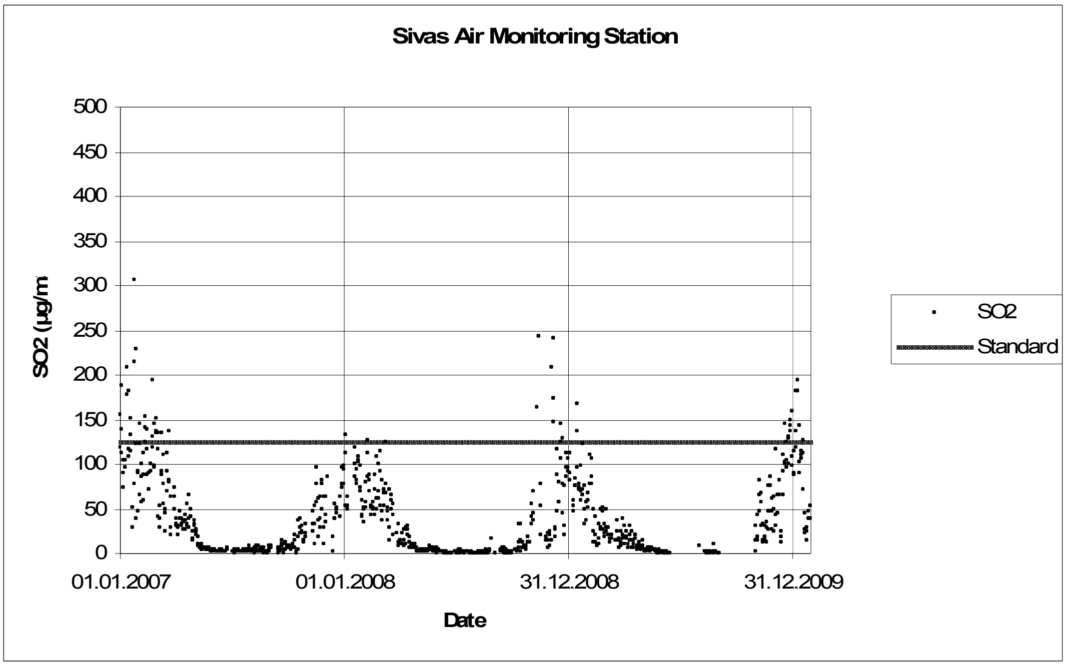

Figure I.16. Measured Daily SO_2 Concentration Measured at Sivas Air Monitoring Station

APPENDIX J

MEASURED PM_{10} CONCENTRATION OF SELECTED AIR MONITORING STATIONS

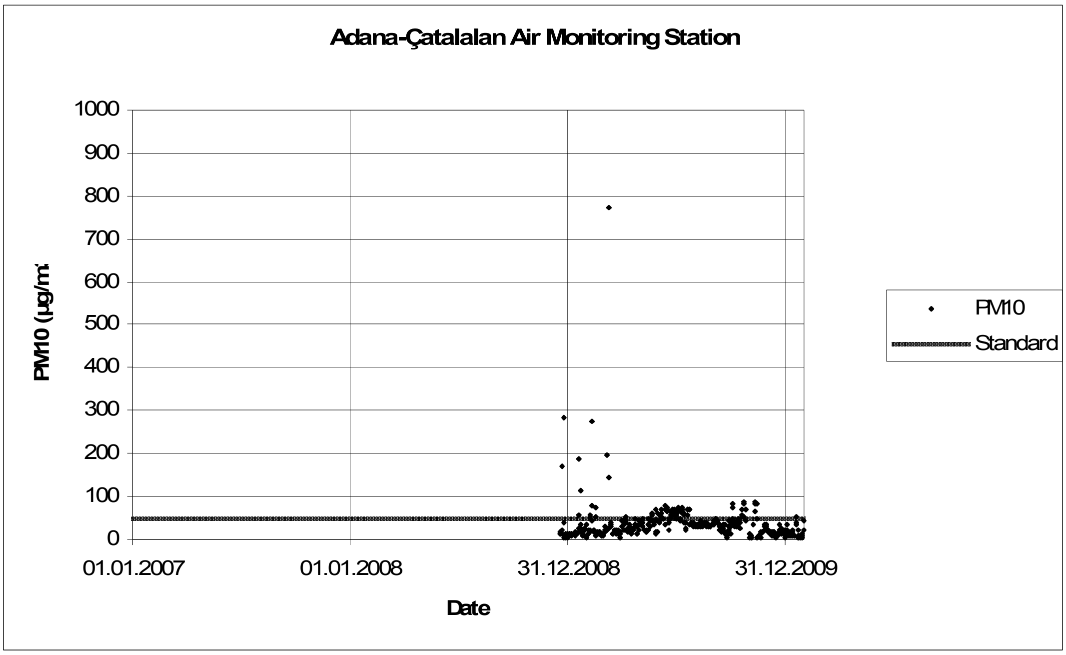

Figure J.1. Measured Daily PM_{10} Concentration Measured at Adana-Çatalalan Air Monitoring Station

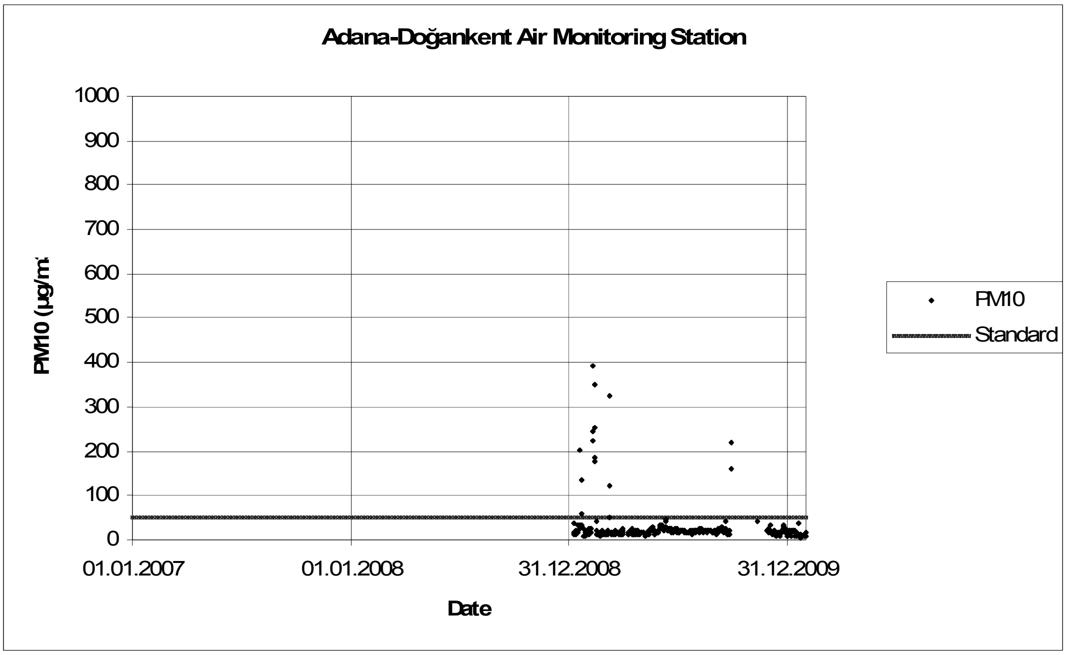

Figure J.2. Measured Daily PM_{10} Concentration Measured at Adana-Doğankent Air Monitoring Station

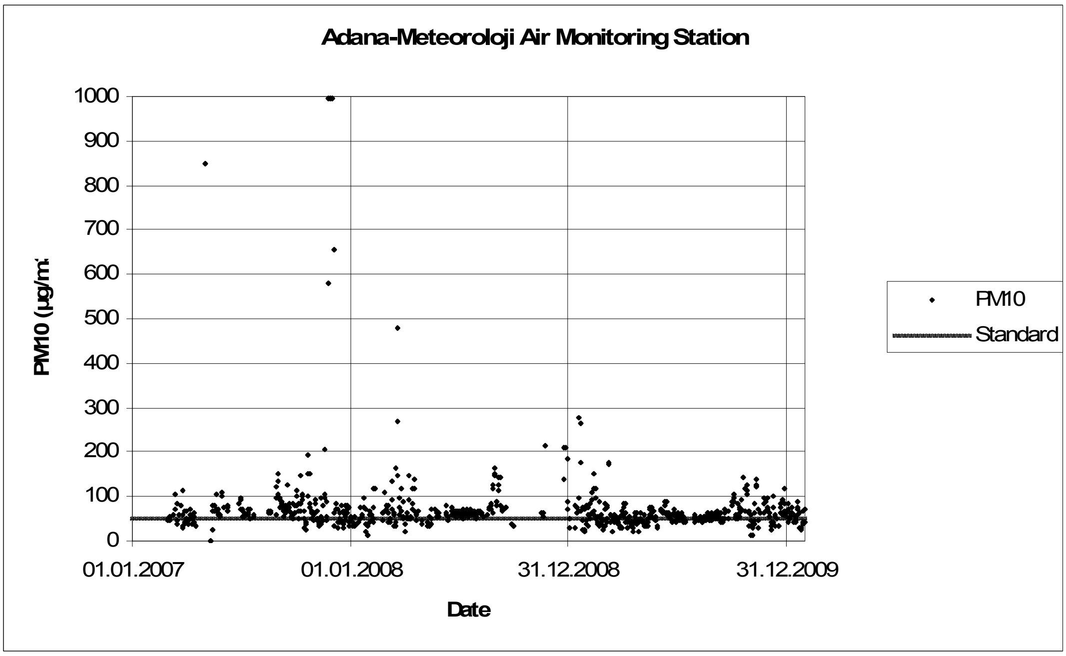

Figure J.3. Measured Daily PM_{10} Concentration Measured at Adana-Meteoroloji Air Monitoring Station

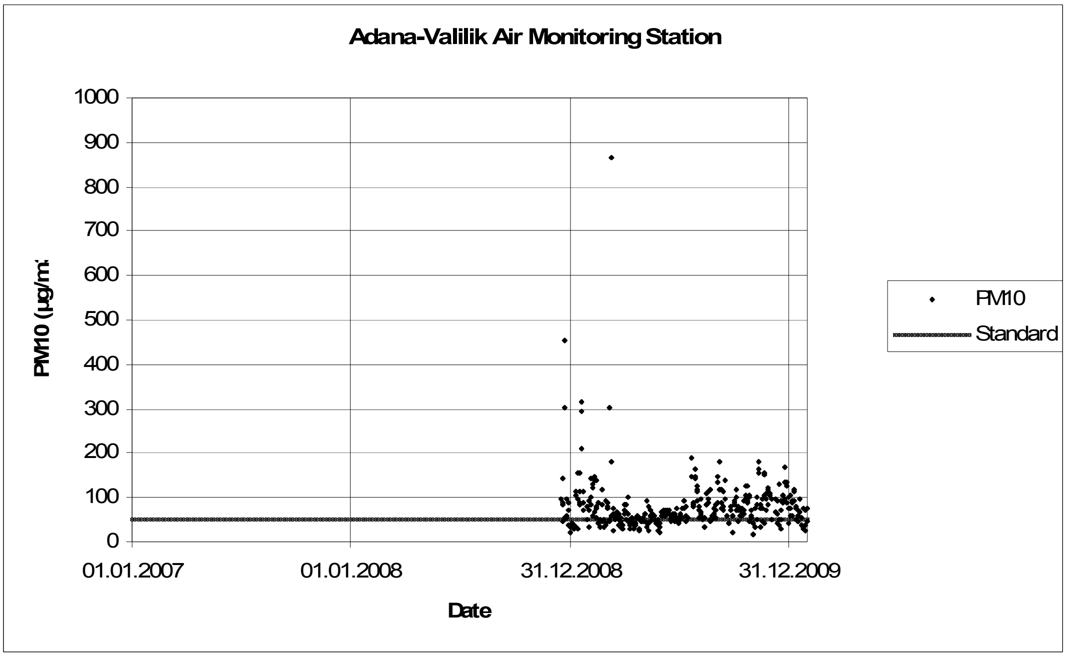

Figure J.4. Measured Daily PM_{10} Concentration Measured at Adana-Valilik Air Monitoring Station

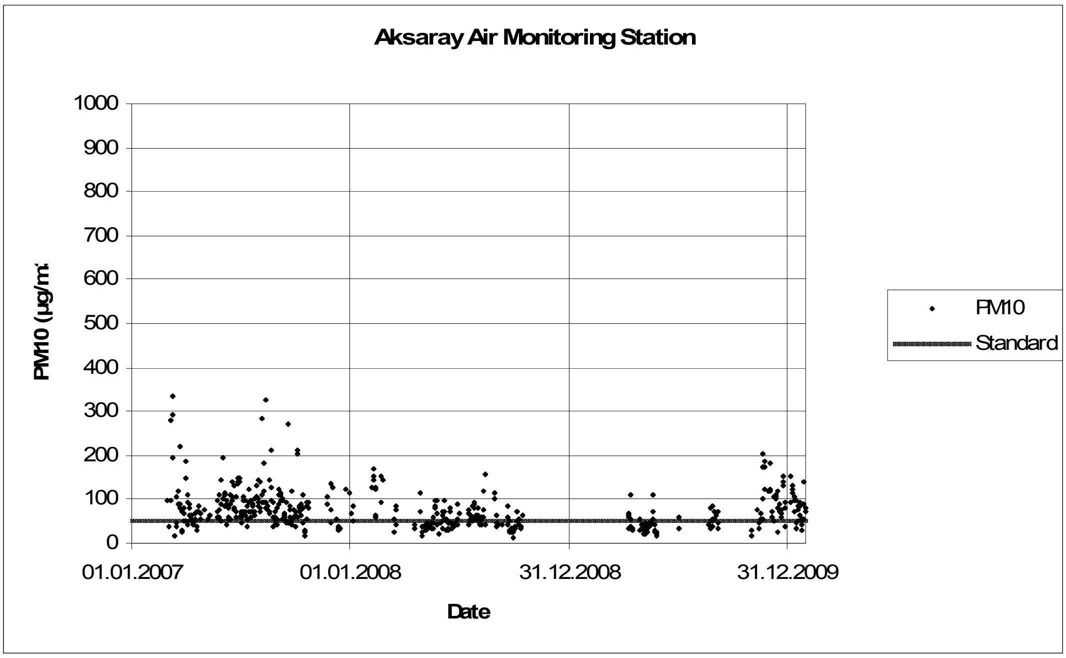

Figure J.5. Measured Daily PM_{10} Concentration Measured at Aksaray Air Monitoring Station

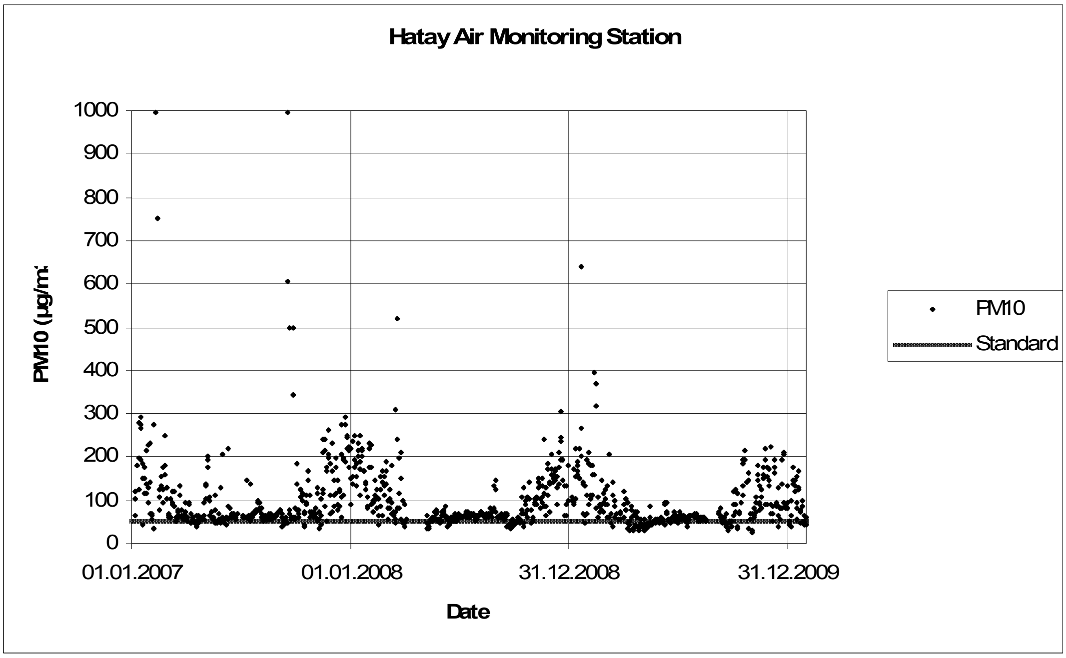

Figure J.6. Measured Daily PM_{10} Concentration Measured at Hatay Air Monitoring Station

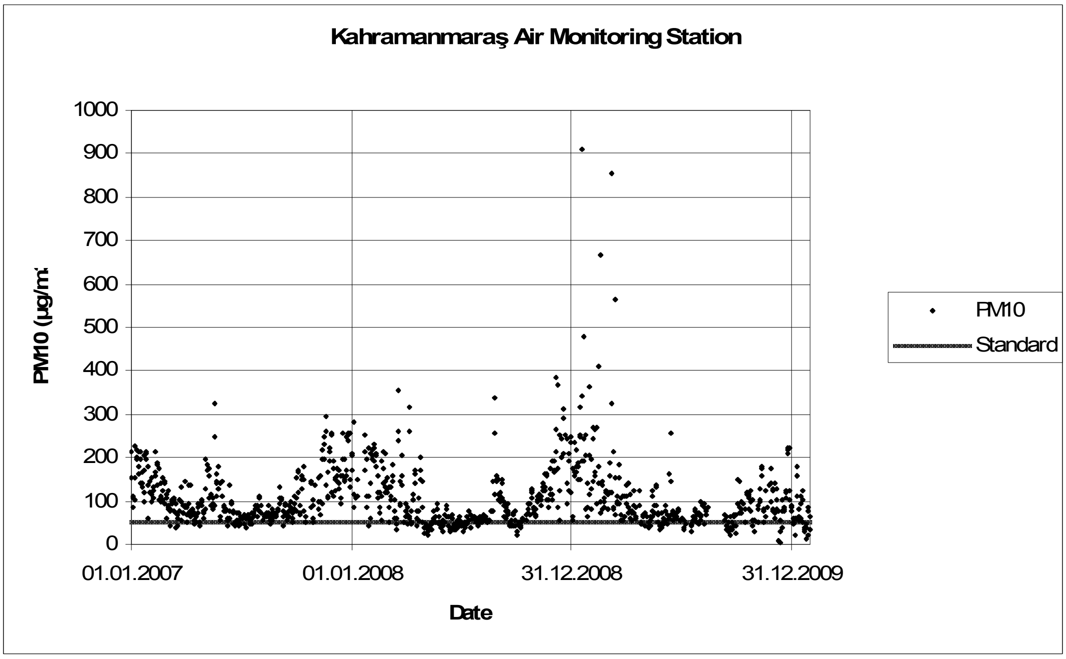

Figure J.7. Measured Daily PM_{10} Concentration Measured at Kahramanmaraş Air Monitoring Station

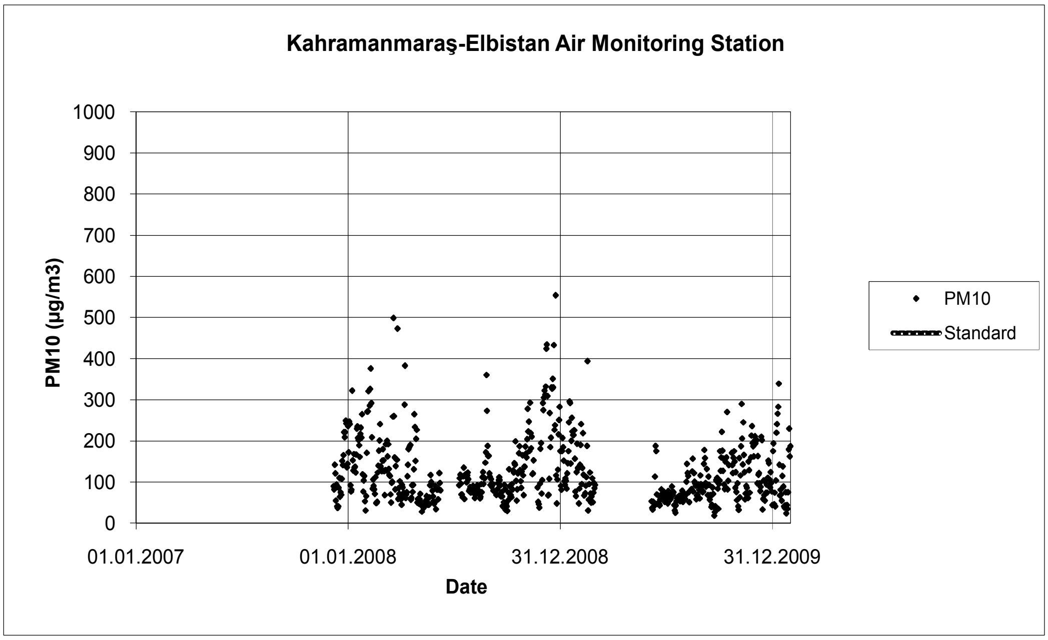

Figure J.8. Measured Daily PM_{10} Concentration Measured at Kahramanmaraş-Elbistan Air Monitoring Station

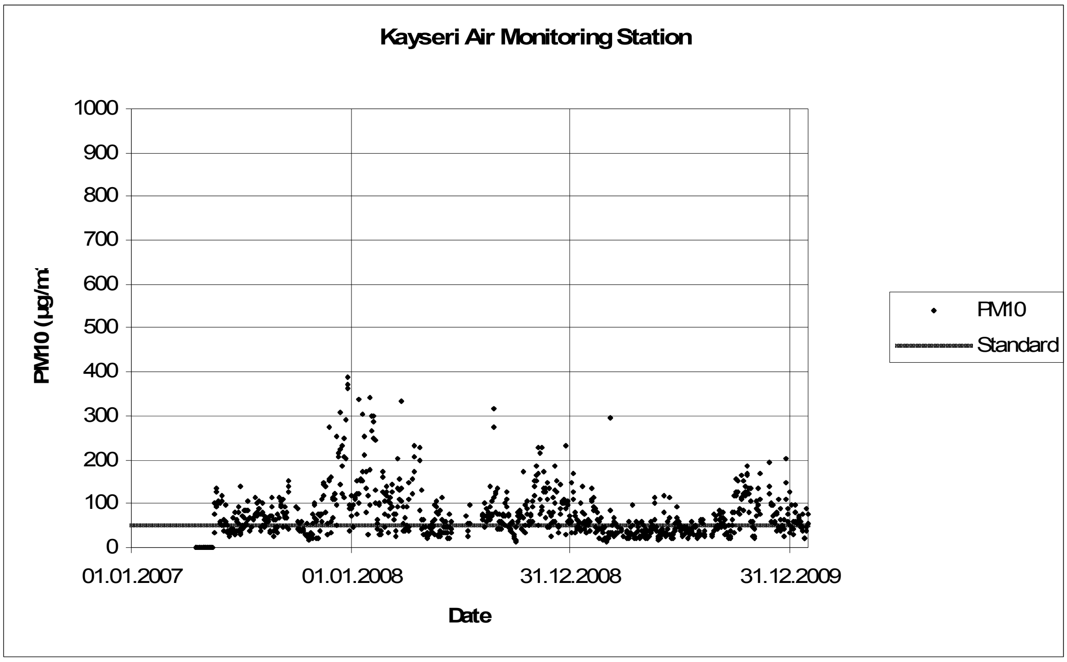

Figure J.9. Measured Daily PM_{10} Concentration Measured at Kayseri Air Monitoring Station

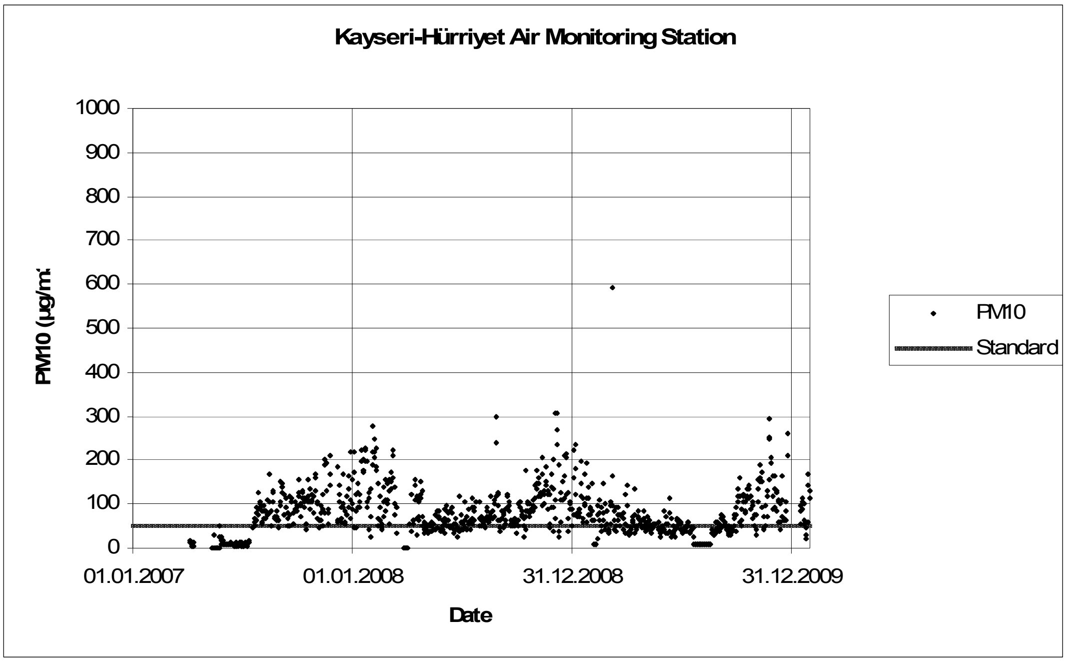

Figure J.10. Measured Daily PM_{10} Concentration Measured at Kayseri-Hürriyet Air Monitoring Station

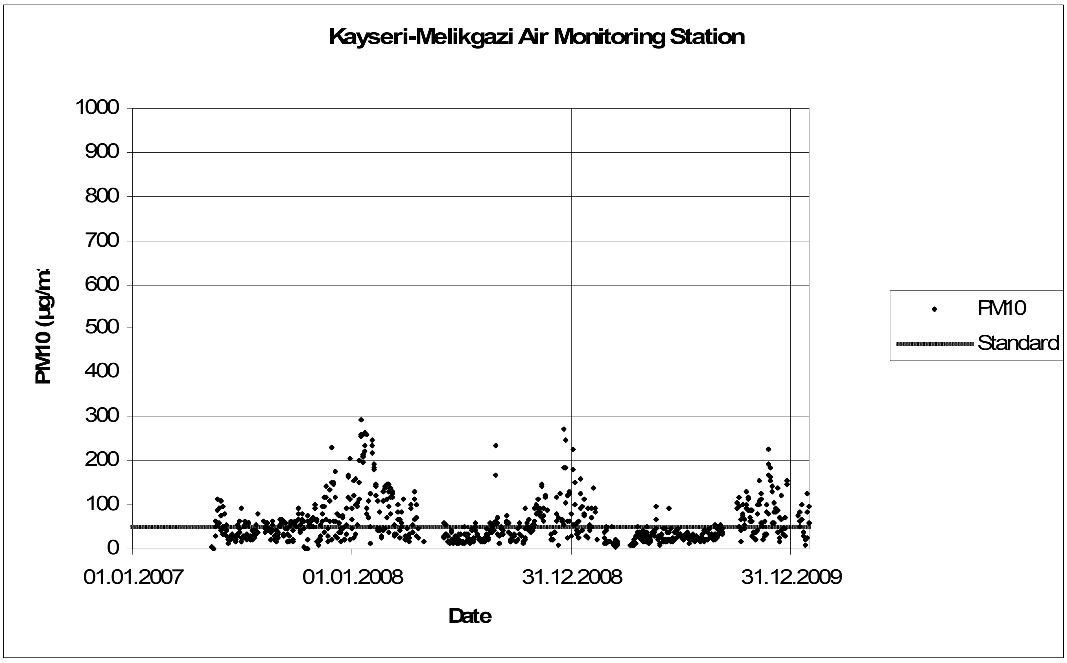

Figure J.11. Measured Daily PM_{10} Concentration Measured at Kayseri-Melikgazi Air Monitoring Station

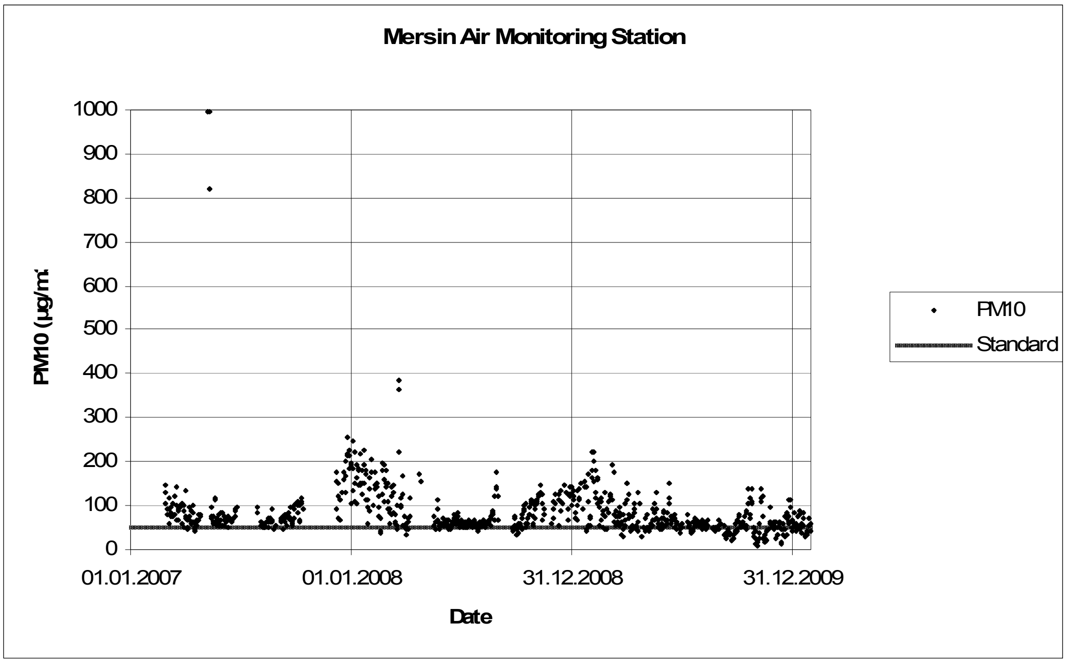

Figure J.12. Measured Daily PM_{10} Concentration Measured at Mersin Air Monitoring Station

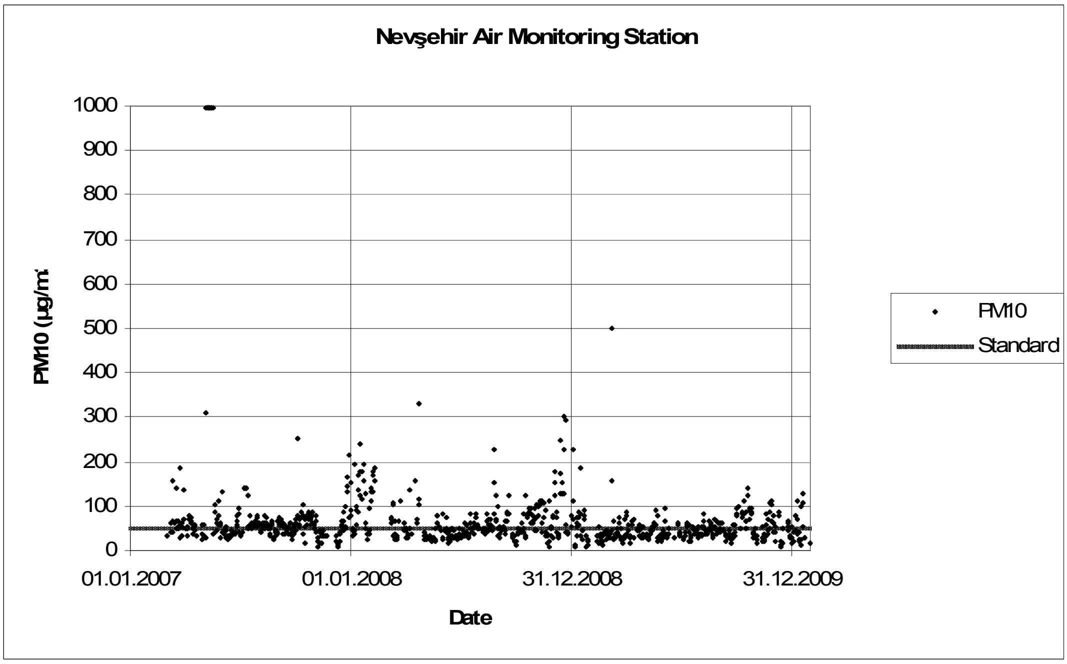

Figure J.13. Measured Daily PM_{10} Concentration Measured at Nevşehir Air Monitoring Station

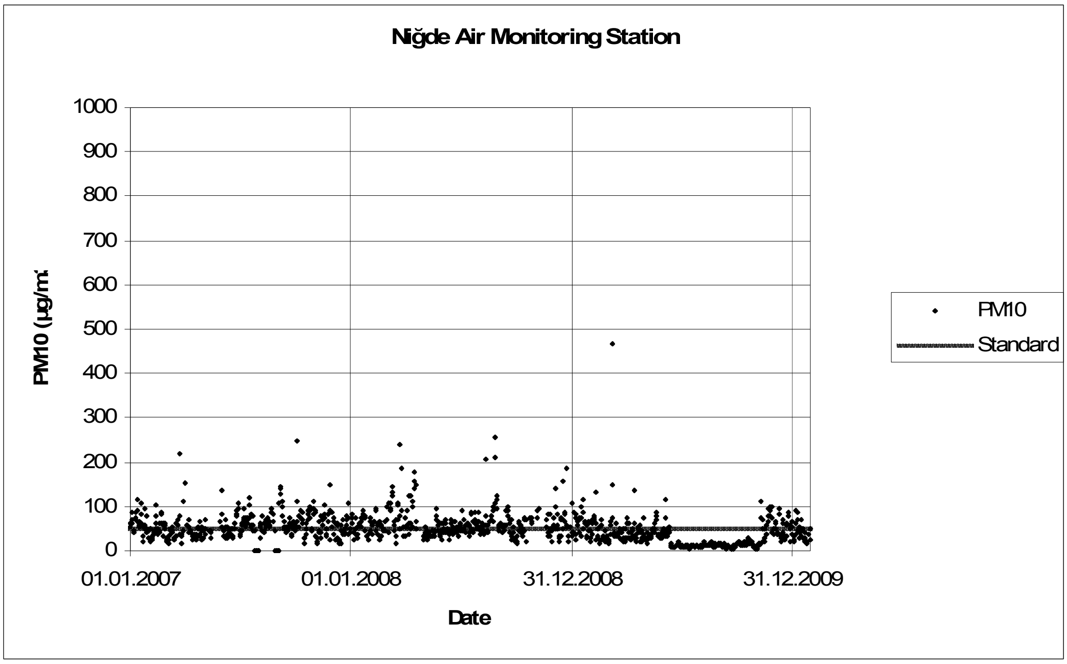

Figure J.14. Measured Daily PM_{10} Concentration Measured at Niğde Air Monitoring Station

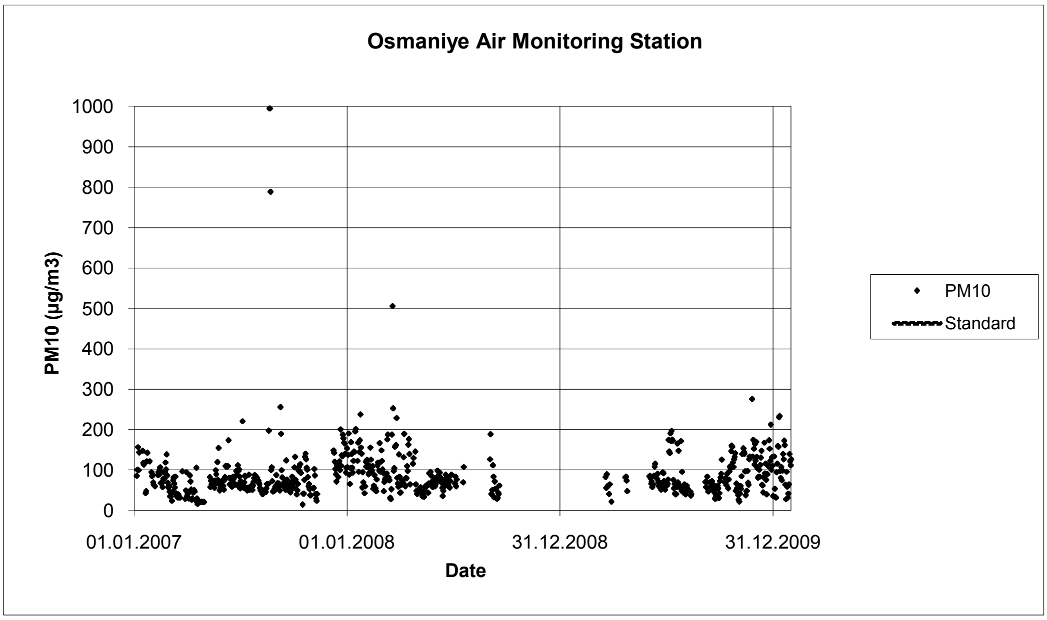

Figure J.15. Measured Daily PM_{10} Concentration Measured at Osmaniye Air Monitoring Station

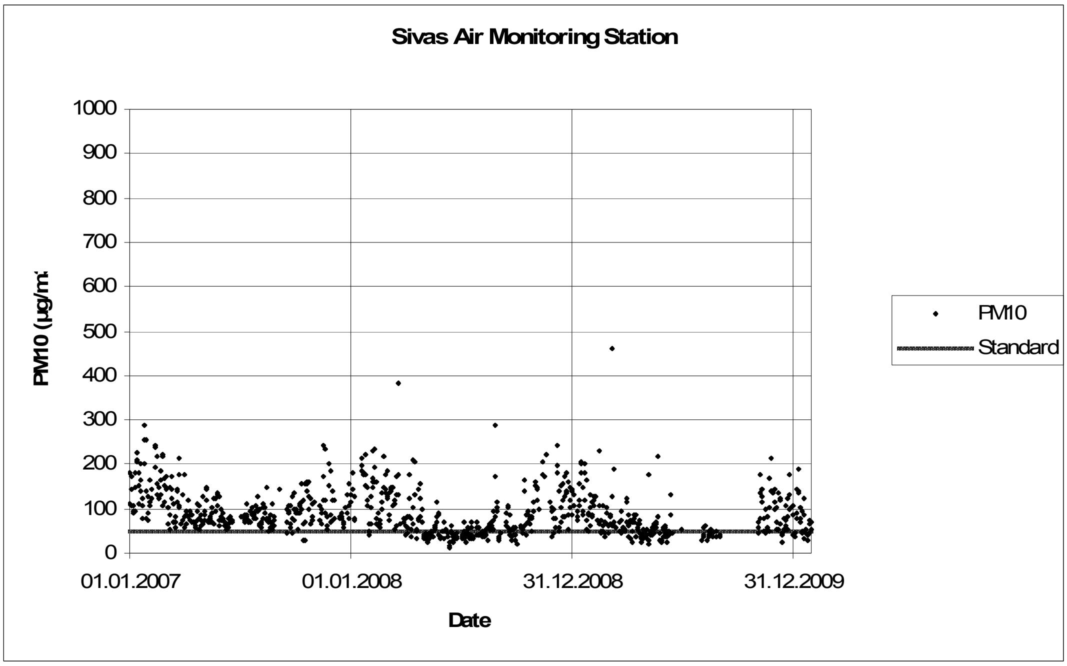

Figure J.16. Measured Daily PM_{10} Concentration Measured at Sivas Air Monitoring Station