UNIVERSITY OF NOVA GORICA
GRADUATE SCHOOL

LEVEL AIR POLLUTION ASSESSMENT IN URBAN AND SUB-URBAN TUNIS AREAS

MASTER'S FINAL THESIS

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Level air pollution assessment in urban and sub-urban Tunis areas

Abstract

This thesis aims to study the dispersion of air pollutants NOx (Nitrogen Oxides), NO_2 (Nitrogen dioxides), SO_2 (Sulfur Dioxide), and PM10 (dusts) in Greater Tunis thanks to statistics provided by the National Institute of Meteorology of Tunisia and the measures taken by the National Agency of Environmental Protection (ANPE) also it aims to study wind and weather types including their effects on meteorological parameters and atmospheric pollutants space distribution in this region. This document supports an initiative to develop and make available a consistent set of tools for analyzing and understanding air pollution data in a free, open source environment.

Initially, knowledge of bibliography (geographical, climatic and demographic) of Tunisia and the Greater Tunis will be presented in order to fit this study. The second chapter will include a descriptive statistical analysis of data based on graphs and schematics that I prepared through software called R CRAN eventually leading to comparisons and conclusions.

The final chapter will seek to identify more closely the perceptions, needs and expectations in terms of information on air pollution and its health impact of various trades in relation to sensitive individuals. To this end, a qualitative survey will be conducted. After this study and considering the different elements collected, the prospects for communication to be favored in the Great Tunis will finally be described.

Key words

Air, pollutants, Greater Tunis, Statistics, graphs, perceptions, exceeded frequencies, prospects.

Ocenjevanje stopnje onesnaženosti zraka v mestnih in primestnih območjih Tunisa

Povzetek

Cilj magistrskega dela je prikazati razpršenost onesnaževal v zraku. Spremljali smo koncentracije NOx (dušikovih oksidov), NO_2 (dušikovega dioksida), SO_2 (žveplovega dioksida) in PM10 (prah) na območju Greater Tunis. Statistični podatki, ki sta jih preskrbela Nacionalni inštitut za meteorologijo iz Tunizije in Nacionalna agencija za zaščito okolja (ANPE) so nam omogočili, da smo lahko opravili študijo vpliva vetra in vremena z vključenimi meteorološkimi parametri na onesnaženost zraka v tej regiji. Rezultati so v skladu s pobudo za razvoj uporabnih orodij za analizo in razumevanje podatkov o onesnaženosti zraka v odprtem okolju.

V nalogi so najprej predstavljene geografske, podnebne in demografske značilnosti Tunizije in območja Greater Tunis na podlagi zbrane literature. Drugo poglavje vključuje opisno statistično analizo podatkov, ki temelji na grafih in shemah, pripravljenih s pomočjo programske opreme imenovane R Cran. To nam je omogočilo primerjave in sklepe.

V zadnjem poglavju bomo skušali opredeliti natančneje zaznavanje, potrebe in pričakovanja v zvezi z informacijami o onesnaževanju zraka in njegovih vplivih na zdravje ljudi. V ta namen bo opravljena kvalitativna raziskava podatkov. Študija, ki vključuje različne elemente, bo omogočala boljše možnosti za komunikacijo, ki bodo v prid območju Great Tunis.

Ključne besede

Zrak, onesnaževalci, Greater Tunis, statistika, grafi, dojemanje, presegle frekvence, pričakovanja**.**

Contents

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List of acronyms

ANPE: National Agency of Environment Protection

RNSQA: National Network of Monitoring of the Quality of the Air

WHO: World Health Organization

CART: Statistical model

ISO 9001: Family of standards related to quality management systems and designed to help organizations ensure that they meet the needs of customers and other stakeholders while meeting statutory and regulatory requirements related to the product.

EU: European Union

NAAQS: National Ambient Air Quality Standards

GIS: Geographic Information System

CO: Carbon monoxide

NO_2: Nitrogen dioxide

NOx: Nitrogen oxides

O_3: Ozone

PS: Solid particles

P10: Mass of solid particles whose average aerodynamic diameter less than 10 microns

SO_2: Sulfur dioxides

H_2SO_4: Sulfuric acid

HNO_3: Nitric acid

VG: Guide Value

VL: Limit Value

NT.106.04: Tunisian Standards for pollutants

BS: Bab Saadoun

BW: Bab Aliwa

RH: Relative humidity

Introduction

The air is an essential element to life; it is composed of 78% nitrogen, 21%oxygen and 1% of other gases. However, air pollution is a complex mixture of compounds emitted by various sources of pollution (primary pollutants) and secondarily formed during chemical reactions occurring in the atmosphere [Hassairi,2010].

Air pollution has taken an important place in social life until the 1950s, marked by a series of major events ("smog" in London in 1952, Seveso accident in 1976 , ...). Today, increasing concentrations of people and economic activities as well as a growing vehicle fleet have contributed to high levels of air pollution in the large cities of developing countries.

Dust, smoke and various toxic gases have threatened our existence and well-being. So, it is important to monitor the quality of air around us before implementing preventing and controlling measures of air pollution.

Air is ubiquitous. Urban focal points are contaminated with Particulate Matter (PM10) densities. The other pollutants present in the core city areas are oxides of sulfur and nitrogen and carbon monoxide. World Health Organization (WHO) and European Union (EU) have set ambient Air Quality Standards. Similarly there is National Ambient Air Quality Standards (NAAQS) for Tunisia. Any pollutant exceeding this standard limit is considered harmful to human health and benign to ecosystem [OMS,1987].

Efforts to measure regularly the air quality levels in Tunisia began in 1994 by the National Agency of Environmental Protection (ANPE). They have used automated air-monitoring stations located in different areas of Tunisia and especially in Tunis. The regulatory framework inherent in the monitoring of air quality and governing air pollution is available since nineteen and is essentially in :

- The standard for cement NT106.05 (1995) on environmental protection limits values for pollutants from cement plants [World Bank,2004] .
- The thresholds limits for exhaust emissions of road transport vehicles (the Highway Code 2004) and for carbon monoxide for gasoline cars and opacity for diesel cars provided by Decree ° 2000-147 of 24 June 2000 laying down the technical and development [World Bank,2004].

- Law n ° 2007-34 of 4 June 2007 on air quality [World Bank,2004].

However, very few studies have been conducted to assess the level of pollution on the Great Tunis and its health effects. In this context is the present work and aims to:

- Assess the level of pollution of major air pollutants on the Great Tunis.
- To compare these levels of pollution to the required standards.
- To assess the evolution of the level of pollution over the last 10 years.

Part I: Bibliographic review

I. Air pollution

I.1.Definition

The “pure air” is normally composed of 78% of N2, 21% of O2 and 1% of rare gases. Air pollution is caused by a change from the normal composition of air, it is characterized by altered levels of quality and purity. This degradation is usually caused by one or more elements (particles, substances, materials ...) whose degree of concentration and duration of presence are sufficient to produce a toxic and/or ecotoxic effect [Ministry of Environment and Sustainable Development, 2010].

This air pollution can cause damage on health, ecosystems and natural resources.

This pollution can take many forms and be:

- brief or chronic,
- visible (smoke) or invisible (pesticides in the air),
- massively emitted or low dose,
- emitted in dispersed quantity (eg pollution from the hundreds of millions of exhaust pipes)
- Local and emitted from a stationary source (eg chimney, factory), or emitted by mobile sources (cars, pesticide applicators, air or sea transport, etc..), All of these sources contribute to global pollution inside or external (eg increase the greenhouse effect due to CO2 or volatile organic compounds in the domestic space);

I.2. Main manifestations of the air

I.2.1. Sources

Pollution of the atmosphere results from the direct release of gaseous or particulate form, harmful to humans or the biosphere, from various human activities, industrial, domestic, agricultural, transportation and combustion variety. So these pollutants are anthropogenic:

- The combustion are a major source of pollutants
- A variety of pollutants with industrial activities

- Evaporation of solvents and fuels

The biosphere also produces natural gas and particles that are found in the atmosphere. This is the case of wind erosion, hydrocarbon emissions from vegetation, production of gas from bacterial decomposition in soils, waters.

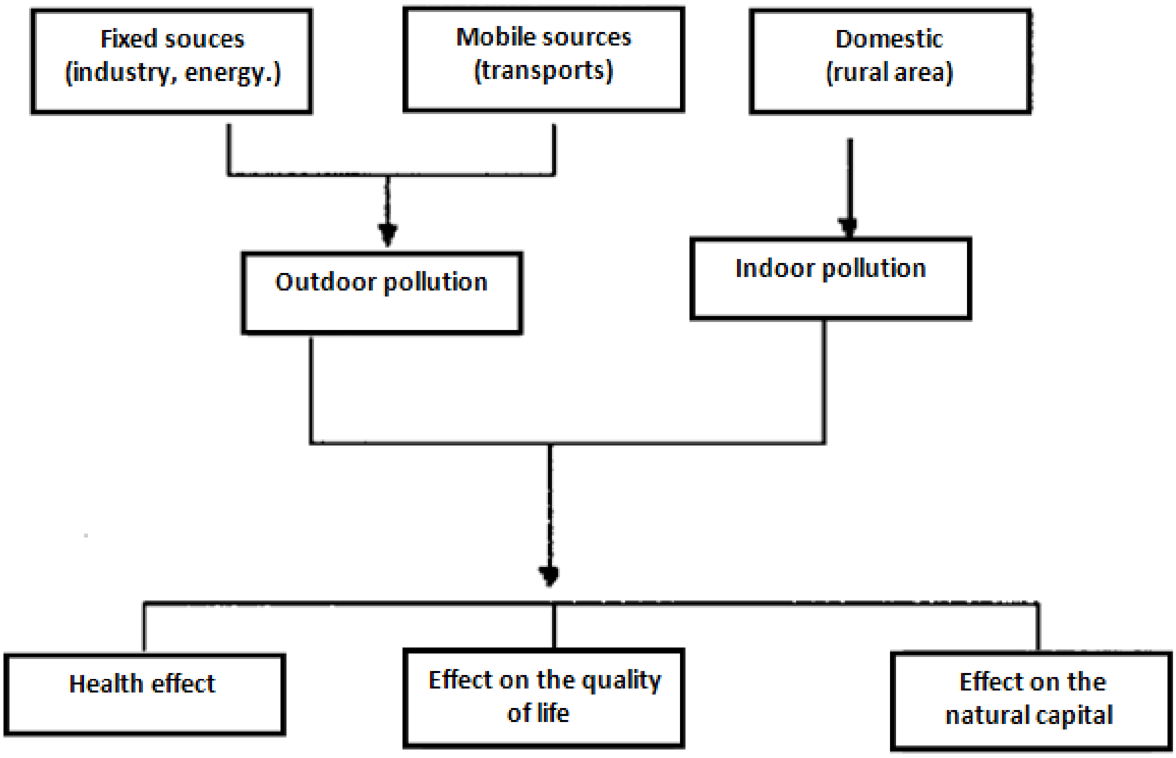

Fig 1 Sources of air pollution and its effects [Gharbi, 2012]

I.2.2. Primary and secondary pollutants

The various pollutants introduced into the atmosphere directly or as the modification's consequence of natural emissions of the biosphere are called "primary pollutants".

Many of them will react chemically, especially under the influence of solar radiation, and provide new components or "secondary pollutants", which are often more harmful to the environment than those who gave them birth. Among these secondary pollutants we have strong acids such as sulfuric acid and nitric acid and strong oxidizers such as ozone [Hassen,2007].

I.2.3. Different levels of pollution

a) The pollution at the local level

The effects of air pollution will occur at different scales of space and time. In urban areas, or industrial sites (Figure 2), emissions are important and primary pollutant concentrations will reach high. It is thus observed high concentrations of sulfur dioxide, nitrogen oxides, particulate matter and hydrocarbon.

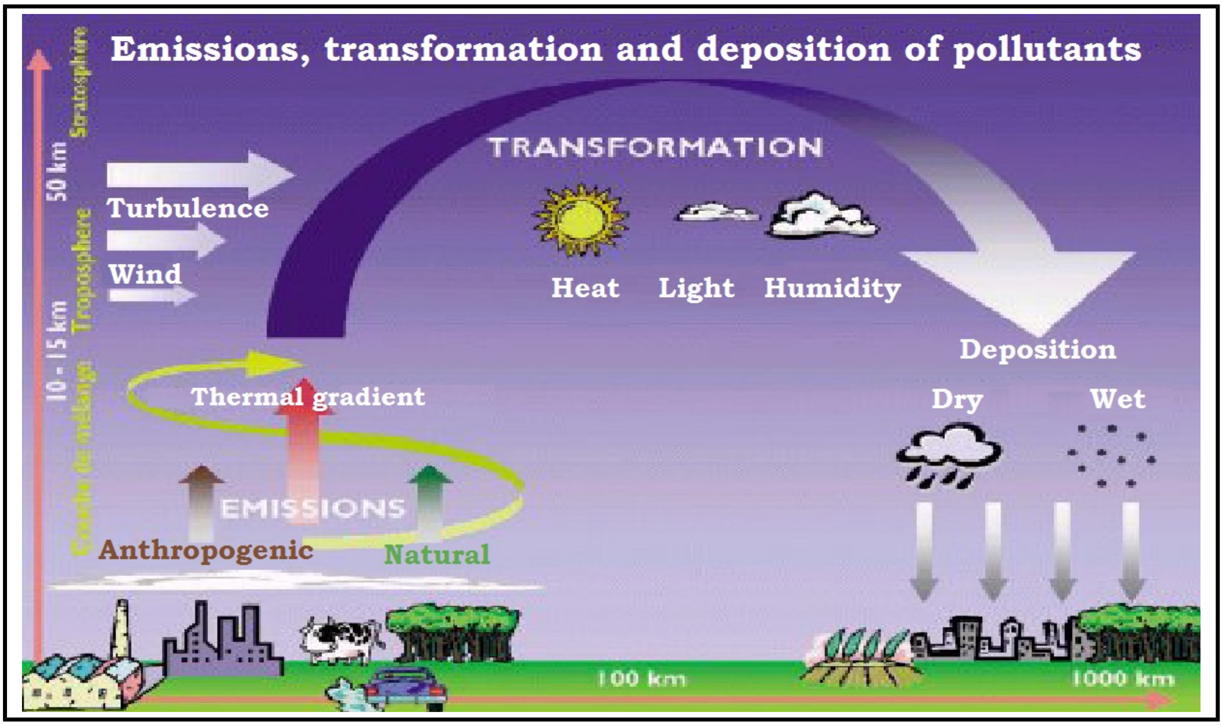

Fig 2 Air pollutants and transfer mechanisms
Source: http://www.cleartheair.nsw.gov.au, 2011

b) Pollution at the regional level

Pollution of the atmosphere is also evident from tens to several hundreds or even thousands of kilometers. The concentration levels are not as high as locally and effects, mainly due to secondary pollutants, will be felt more insidiously, with an acidification of precipitation, increasing the oxidizing power of the air. This results an acidification of surface waters and forest dieback [Fontan, 2003].

c) Pollution across the planet: the greenhouse effect and the ozone hole

Finally the air pollution is a phenomenon affecting the entire planet, with two types of events. The first is the destruction of the ozone layer in the stratosphere, accompanied by a dangerous increase, to humans and the biosphere, of ultraviolet radiation that reaches the ground. The second is the increased concentration of certain gases chemically unreactive in the troposphere and can therefore accumulate as they are issued and not destroyed [Fontan, 2003].

I.3 Characteristics of the most important pollutants and their main effects on the health

- **Nitrogen oxides (NOx)**

This term includes nitric oxide (NO) and nitrogen dioxide (NO_2). NO, mainly emitted by traffic, comes from the combustion reactions. It is then oxidized to NO_2 in the atmosphere. Nitrogen oxides are respiratory irritants that can cause impairment of respiratory function. They are the cause of acid rain and ozone formation [El Melki,2007].

- **Sulfur dioxide (SO_2)**

This pollutant, mainly industrial origin, comes from combustion plants (heavy fuel oil, coal, gas ...). It is very irritating to mucous membranes and respiratory tract. It can cause lung edema and bronchitis. It is partly responsible for acid rain [El Melki,2007].

- **PS: Particles**

Particulate matter is comprised of very small solids or liquids, such as dust, soot, aerosols, fumes, and mists. The dust particles are composed of different compositions and pollutants size between 0.001 and 50 microns. They are most often, the result of the meeting in the atmosphere of several sources of pollution. They contain toxic substances like heavy metals or hydrocarbons. Only particles of size less than 10 micrometers (PM10) remain suspended in the air. These fine particles (PM10) are mainly emitted by diesel vehicles. Fine particles can penetrate deep into the alveoli and cause respiratory problems among others, and could cause cancer. They also block plant respiration and degrade buildings by their deposits [El Melki,2007].

- **Ozone (O_3)**

Tropospheric ozone is a pollutant called secondary because it results from chemical transformations under the effect of solar radiation and primary pollutants such as nitrogen oxides and volatile organic compounds [El Melki,2007].

- **The carbon monoxide (CO)**

Carbon monoxide comes from incomplete combustion of organic matter (gas, coal, oil or wood fuel), often due to poorly regulated facilities. Strongly emitted by motor transport and therefore present in close proximity to roads, carbon monoxide is measured primarily at sites of traffic. It is flammable, odorless and colorless, which increases it dangerousness.

The effects vary depending on the nature of the chemical compound. They range from simple discomfort to olfactory irritation, decreased respiratory capacity to mutagenic and carcinogenic, especially established for benzene [Penard-Morand, 2008].

- **Heavy metals**

Present in the state of traces in the atmosphere, toxic metals are mainly in particulate form, which enables them on the one hand to be transported over long distances, and secondly to enter the respiratory tract of living organisms. They come mainly from burning coal, oil, industrial metals and waste treatment, and other industrial processes. Heavy metals have a density greater than 4.7 g/cm^3 [Penard-Morand, 2008].

  - **lead**

In air, the lead came until the early 90s in almost all transport. The introduction of unleaded fuels has caused a gradual decrease in concentrations near roadways. Currently, the share of road transport is negligible. The main sources are waste incineration, metallurgy and some other industrial processes such as crystal. Lead can cause (high dose) in children brain development disorders and psychological disturbances so school learning difficulties, these symptoms form a pathology being called lead poisoning [OMS,2000-2008].

  - **cadmium**

It also comes mainly from waste incineration and industrial processes such as metallurgy [OMS,2000-2008].

- **nickel**

It is present in heavy fuel oil in emerging sectors the largest consumers of this energy product, and petroleum refining [OMS,2000-2008].

II. Control strategy for monitoring the air quality:

II.1. European monitoring strategy:

As we enter the third millennium, the monitoring strategy has been reviewed and includes a regional dimension. The networks realize a common reflection, leading to more comprehensive monitoring of air in each region for full control of the whole territory, the main elements considered are:

-The state of air quality in relation to regulatory thresholds

-The population exposure to pollution

-Local issues related to land use and air quality

-The specific local problem (protected areas, sensitive facilities, agricultural areas using pesticides, emitting activities of a specific pollution) [National Network for Monitoring Air Quality 2000-2008].

II.2. Additional tools adapted to the questions and issues:

Monitoring of air quality involves different and complementary ways: fixed measurement stations cover the region, means for mobile measuring that perform one-off measures and the numerical models used to make predictions and mapping of more and more reliable. These tools combine to make an inventory of air quality, the one we breathe today, that we breathe yesterday or five years ago, but also of tomorrow. All these means of measurement and studies are used to qualify the air from any point in the region, and can help with decisions to develop the territory [Fontan, 2003].

II.3. Tunisian monitoring strategy

a) Criteria and indices of air quality

The air quality is an essential component of citizens life. Thus, it is one of their main environmental concerns. The air quality is influenced mainly by human polluting activities, urban sprawl that creates residential areas near existing production units such as cement, phosphate plants, refineries, steel plants and stone quarries. In some cases the quality of fuels used is a major cause of air pollution.

Tunis roads are less congested than those of Egypt and Morocco cities, although pollution from traffic and industry remains a serious problem. At the national level, energy production is responsible for 31% of air pollution, while transport contributes up to 30% [Sophia Antipolis, December 2001].

In the light of results from surveillance operations carried out by the national network of monitoring air quality using fixed or mobile, it turns out that the air quality is, in general, good even if sometimes we observed exceedances vis-a-vis Tunisian standards as a result of particular climatic conditions and emerging polluting activities. Such situations are observed at the intersections of major roads or residential areas overflowing on industrial clusters For this reason, the enactment of a law on air quality has become necessary to ensure:

- Preserving the quality and safety of the atmosphere.
- The protection of public health and ecosystems against emissions.
- Establishment of a system of early warning
- Inclusion in the development plans of the impact of climate change and greenhouse gas emissions in strategic sectors.
- Upgrade the national network to make it a national reference complies with international quality standards.

To achieve these objectives, the Department will undertake, within the framework of international cooperation and primarily with the French Development Agency which granted to Tunisia a donation of 1.7 million Euros, the following actions:

Develop the legislative framework for the monitoring of air quality in industrial installations.

Complete the installation of the national network for monitoring air quality through the acquisition of 15 new stations, so that the total number of stations reaches 25 by the end of the XIth Plan [ANPE 2000-2010].

b) Presentation and composition of the Tunisian National Network for Monitoring Air Quality RNSQA:

The national monitoring network of air quality (RNSQA) was created in 1996 within the National Agency of Environmental Protection. It is indeed a coherent system to read the air quality day by day in areas most affected by this phenomenon as the big cities and industrial zones. Sixteen years of existence and already fifteen fixed functional stations and a mobile laboratory in place (Fig.3) . Moreover, it is envisaged to expand the network to 25 stations around the year 2015, thus covering all the cities of Tunisian territory.

Fig 3. Stations for monitoring the air quality in Tunisia (Source: RNSQA)

c) Membership of the network

The National Network Monitoring air quality is composed of 15 fixed stations including five new stations all connected to the central post located within the ANPE.

The stations are equipped with various measuring instruments and analyzers pollutants such as sulfur dioxide, nitrogen oxides, solid particles, carbon monoxide and ozone. They also include devices for meteorological measurements.
Measurements are continuous and the results are archived at the ANPE and are distributed in the monthly bulletin of the network (Fig.4).

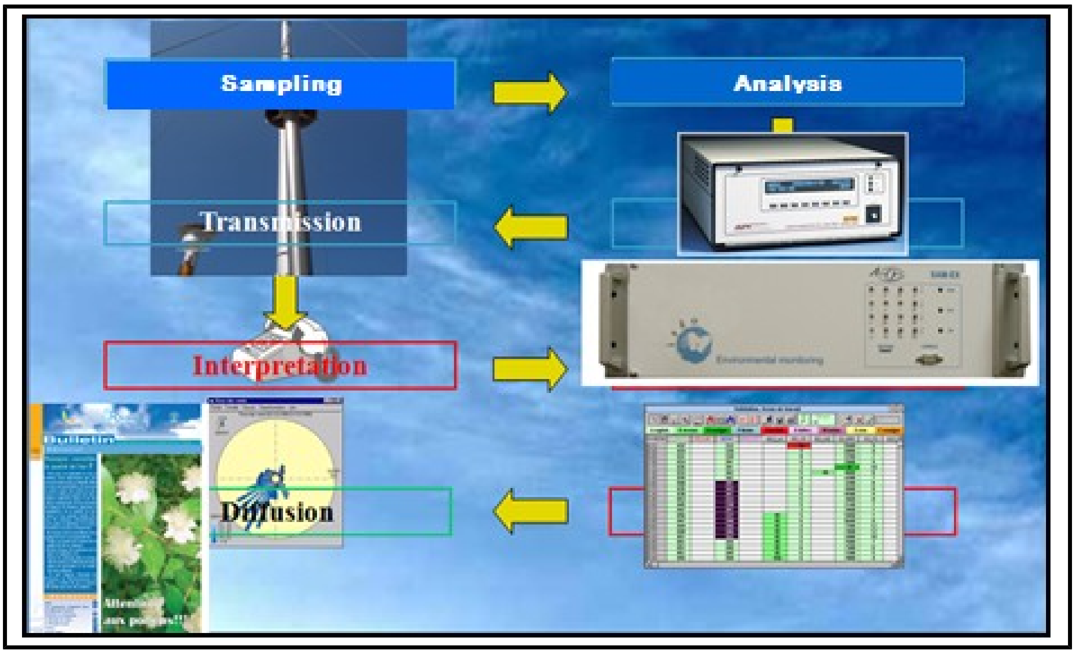

Fig 4. Chain of environmental information (Source: RNSQA)

d) Objectives of the network

- The national monitoring network of air quality has several objectives such as [4]:
- Monitoring of the evolution of air quality,
- Specifying the nature of air pollution and reporting the limit values of exceedances if they exist to prepare response plans, the provision of necessary information and indices of atmospheric environment to Tunisian Observatory of Environment and Sustainable Development (OTED) and all stakeholders in this field,
- Fighting against all sources of pollution, nuisance and all forms of environmental degradation,
- Proposing to the competent authorities any measures of a general nature or specific and designed to ensure the implementation of state policy in the fight against pollution,

- Developing a model of dispersion of pollutants in the atmosphere to determine the most polluting areas requiring attention,
- The achievement of sectoral studies and to provide specific information needed to find appropriate solutions and ensure the effectiveness of procedures that have been taken or will be taken to reduce adverse effects following the implementation of new industrial projects and growth of means of transport,
- The publication of monthly reports on the air quality in Tunisia distributed to members involved in the environmental field,
- The presentation of information on the concentrations of gaseous pollutants from fixed stations for the public through the light board. The first panel was installed in place of the Avenue Habib Bourguiba.

e) Locations of stations in the Great Tunis territory

The stations are installed in different parts of the capital territory and especially in large cities and high density areas with industrial characters. Indeed, depending on the area, stations are classified differently as shown in the table below [ANPE 2000-20010].

Table 1. Fixed monitoring stations on the Great Tunis territory (source: ANPE)

Location	**Class**	**Year of installation**
Rades sports city located in Rades	Urban background station	1996
Industrial area of Ben Arous GP1 Km 8 located in Ben Arous	Station near industrial activities	1997
Place Bab Saadoun Tunis	Station near the Traffic	2002
suburban park Nahli Ariana	Suburban background station	2004
Urban Park El Mourouj	Urban background station	2004
City of science Ariana	Station near the Traffic	2006
Bab Aliwa Tunis	Urban background station	2007
Manouba	Urban background station	2007
City Ghazela	Urban background station	2007

f) Mobile laboratory

The RNSQA has a mobile measuring station for measuring conventional pollutants and also measure meteorological parameters.

In the area not equipped with fixed stations, the mobile laboratory can perform a quick response but it can also act at the request of municipalities that want to characterize air pollution in the region.

It can also perform a preliminary study for the location of base stations.

III. Regulatory framework and policies followed by the Tunisian government to fight against air pollution

The regulatory framework inherent in monitoring air quality and regulating air pollution in Tunisia is summarized essentially on :

- The Tunisian standard on air quality: NT 106 04 (1994) on the protection of the environment: limit values and guide values for certain pollutants into the air.

- The Tunisian standard relating to air quality NT 106 05 (1995) on the protection of the environment - the emission limit values of pollutants from cement

- The emission of exhaust gases from road transport vehicles (1996) and for carbon monoxide for petrol cars and opacity for diesel car.

- Thresholds emission limits of exhaust road transport vehicles (highway code 2004) and for carbon monoxide for petrol cars and opacity for diesel cars provided by Decree ° 2000-147 of 24 June 2000 laying down the technical and management.

- Law n ° 2007-34 of 04 June 2007 on the quality of the air.

- The decree establishing the limits of the source of air pollutants from stationary sources, dated 28 September 2010 which came further strengthen the regulatory framework for monitoring air quality including pollution caused by various industrial activities [RNSQA,2010].

Then, Tunisia has issued June 4, 2007 Law n ° 2007-34 on air quality. The law includes five chapters:

- Chapter I: general provisions
- Chapter II: conservation measures of air quality
- Chapter III: measures of prevention of air pollution from mobile sources
- Chapter IV: prevention measures of air pollution from stationary sources
- Chapter V: the recognition of offences, penalties and transaction

➔ Chapter I: general provisions

This law aims to prevent, control and reduce pollution air and its negative impacts on human health and the environment and to establish procedures for the quality control of the air, in order to make effective citizen's right to a healthy environment and sustainable development.

➔ Chapter II: conservation measures of air quality

The National Agency of Environmental Protection is responsible for:

- Monitoring the air quality and its impact on the environment
- The creation of a national network for monitoring air quality
- The development of conservation plans for air quality on urban area.

The Ministry of Public Health is responsible, in coordination with the ANPE for:

- Control, monitoring and evaluation of air pollution impacts on human health
- Taking the necessary measures to protect man and his environment.

➔ Chapter III: measures of prevention of air pollution from mobile sources

Urban transport plan must take into account:

- the balance between the need for movement and the protection of public health and the environment
- Guarantee the flow of traffic

- Organization and coordination of transport modes through the appropriate and optimal use of road network
- Promoting modes of transport less polluting and more energy efficient

This plan must adopt the following guidelines:

- The reduction of categories of transportation the most air pollutants;
- The development of public transport and transportation energy efficient and less polluting;
- More efficient use of the main road network, including its distribution among different modes of transport in order to reduce air pollutants.

Tunis is currently investing 2 billion $ in improving its public transport network. In November 2008, government completed work to extend light rail network to the south (6.8 km further), and in December 2009, opened another extension of 5.3 km to the west.

Two additional extensions are under construction. A suburban network is planned for 2016, and the city also plans to launch 14 new bus corridors (90 km).

Fig 5. Tunisian light rail

➔ Chapter IV: prevention measures of air pollution from stationary sources

- Obligation of the operators to equip their new installations of equipment and technologies that are able to prevent and reduce air pollutants at the source
- Some operators must control air pollutants at source and connect their facilities to the national network for monitoring air quality

- Fixation of limits in pollutant emissions not to be exceeded
- Obligation to provide information to operators of any incident
- Obliging operators of existing facilities that emit pollutants into the air, to limit or reduce air pollutants at source (within a maximum period of three years from the date of enactment of decree establishing these limits)

➔ Chapter V: the recognition of offences, penalties and transaction

- Infringements of the provisions of Chapter IV are subject to fines ranging from 100 to 50 000 DT
- The competent court may order the closure of the facility in violation
- In case of emergency, the judge may order suspension of the activity causing pollution until the installation of new equipment or performing necessary repairs to reduce pollutants at source
- The court may also order the permanent closure of the facility, if it is established that the limit values is inevitable, once the activity is resumed

Part II: Description of the study area

I. Characterization of the study area

The study area was defined by the urban and sub-urban units of Greater Tunis. According to the 2004 census of the National Institute of Statistics of Tunis, these units include four governorates: Tunis, Ariana, Ben Arous and Manouba.

II. Topography and climate

Tunis is the most populous city and capital of Tunisia. It is also the capital of the governorate since its inception in 1956. Located north of the country, in the Gulf of Tunis which it is separated by the lake of Tunis, the city lies on the coastal plain and the surrounding hills.

The city of Tunis is built on a series of hills sloping down to Lake of Tunis but with a steep slope in the opposite direction (above the sabkha Sijoumi). The climate of Tunis belongs to the Mediterranean climate characterized by cool, rainy season and a hot dry season. It owes its essential features at the latitude of the city, the moderating influence of the Mediterranean and at north to the relief of the Tell.

Winter is the wettest season of the year, and it falls over a third of annual rainfall during this period, representing a rainy day every two or three days. The sun still maintains certain sweetness: the changing temperatures average between 7 ° C in the morning and 16 ° C in the afternoon. Frosts are very rare. In spring, it falls less rain: a total rainfall decreases by half. The sunshine becomes dominant over the month to 10 hours on average per day in May. The temperatures are felt, varying between March 8 and 18 ° C in May between 13 and 24 ° C. This season may also experience a heat wave; Tunis has already recorded record temperatures of 40 ° C in April and May. In summer, rain is totally absent and the sunshine is maximum. The mean temperatures are very high. Sea breezes mitigate the heat, but sometimes the sirocco reverses the trend. In autumn, it started raining again, often during brief storms, which can sometimes promote rapid flood or even floods in some parts of the city. November usually marks a thermal break with changing temperatures average between 11 and 20 ° C [Hassen, 2007].

The city of Tunis, whose surface area has increased significantly during the second half of the twentieth century, now spans several governorates: Governorate Tunis hosts a minority of the population of the town while the suburbs extends the governorates of Ben Arous, Ariana and has Manouba (Figure 6).

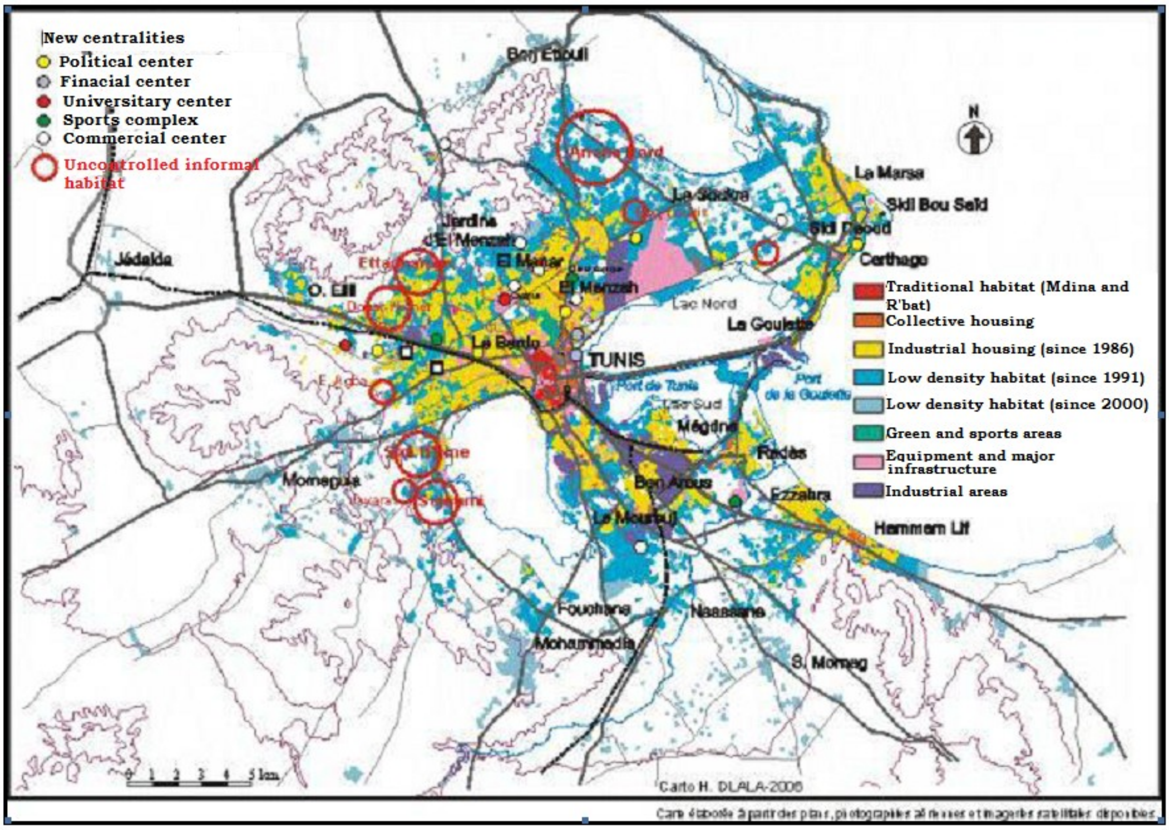

Fig 6. Location of Commons and land use, urban unit of greater Tunis
(Source: INS 2008)

III. Description the study area population

The Tunis district represented in the last census in 2004, a population of 2,408,400 with an average density of 890 022 inhabitants per km^2. The table shows demographic data, area and population density of governorates defined in the study area the governorate of Tunis alone represents 42% of the district population against 20% in Ariana, Ben Arous 23% and 15% in the Manouba governorate (table 3).

Table 2. Population distribution in the study area, Census 2004 INS

Governorate	Population	Surface (km²)	Density (hab/km²)	%
Tunis	996400	356	2798.87	42
Ariana	483500	356	1358.14	20
Ben Arous	565500	790	715.82	23
Manouba	363000	1204	301.49	15
District-Tunis	2408400	2706	890.02	100

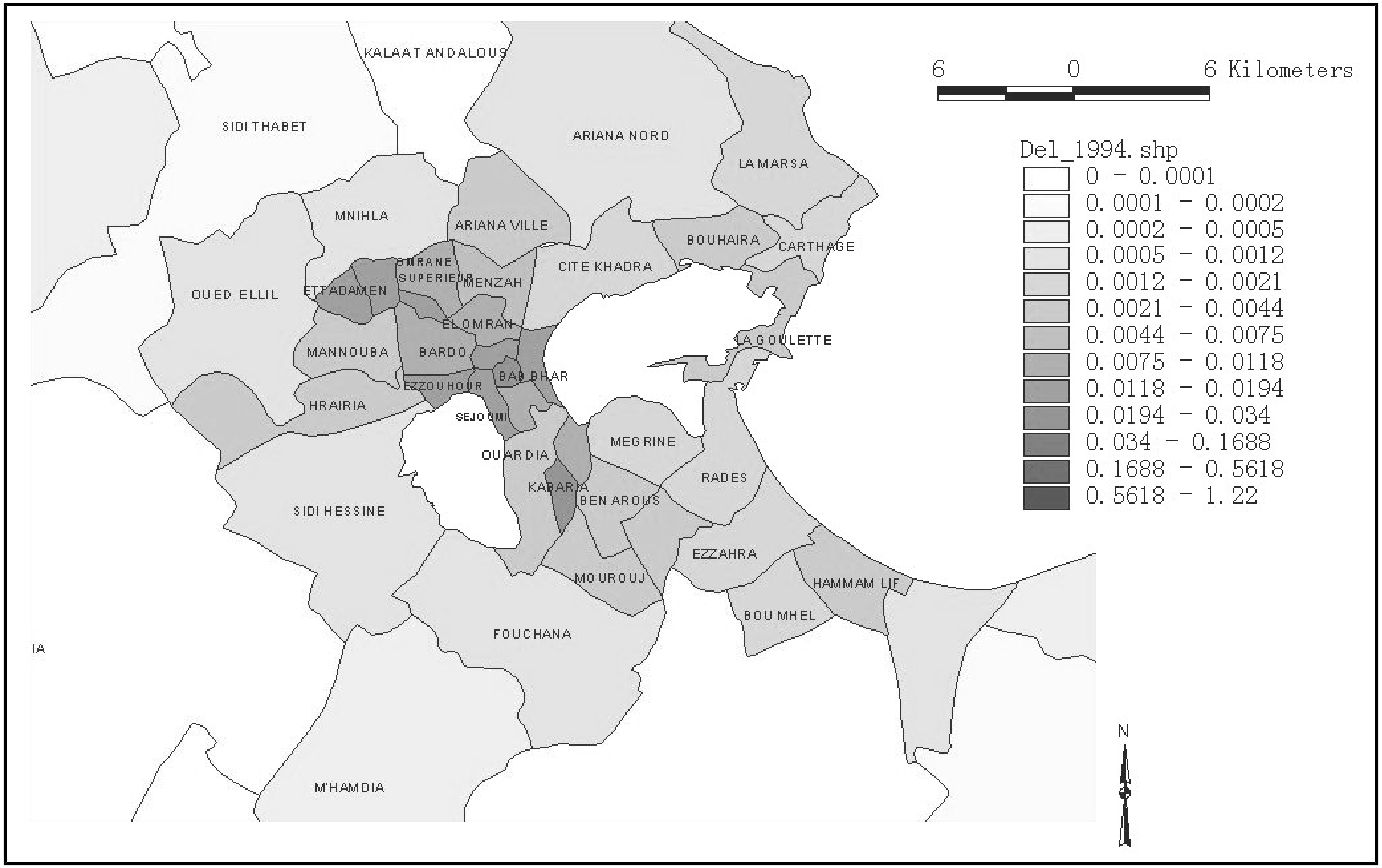

Fig 7. Great Tunis population

Part III: Issues, objectives and methodology of work

I. Preface

To achieve objectives, I conducted a retrospective study from different sources of information by collecting data on pollutants in the urban area of Tunis from the year 2003 to the year 2010.

In this present work, I limit my study to the assessment level of NO_2, SO_2 and particles PS in the air of the Great Tunis.

This work has been performed following the following steps:

- The choice of study area based on the heterogeneity of the nature of the environment to compare and deduce.

- The study of air pollution on the Great Tunis by collecting data from the National Network for monitoring air quality created by the National Agency of Environmental Protection (ANPE). These data were collected first, then we proceed with cleaning and validation, then entered into the software R-Cran to get curves and graphs that can guide and help us to emit the appropriate conclusions for each medium and compare it to other study areas in order to determine the causes of air pollution and propose future perspectives to minimize pollution.

II. Choice of the study area

The choice of the study area was based on the following criteria (INVS, 1999):

- Geographic: urban area, industrial areas, suburban areas;

- Presence of measurement stations;

- Demographics: Presence of the labor force over the area (capital congestion, shuttle to work, hospital attractiveness).

- Weather: humidity, precipitations and wind direction that can influence the dispersion of the pollutant in the area.

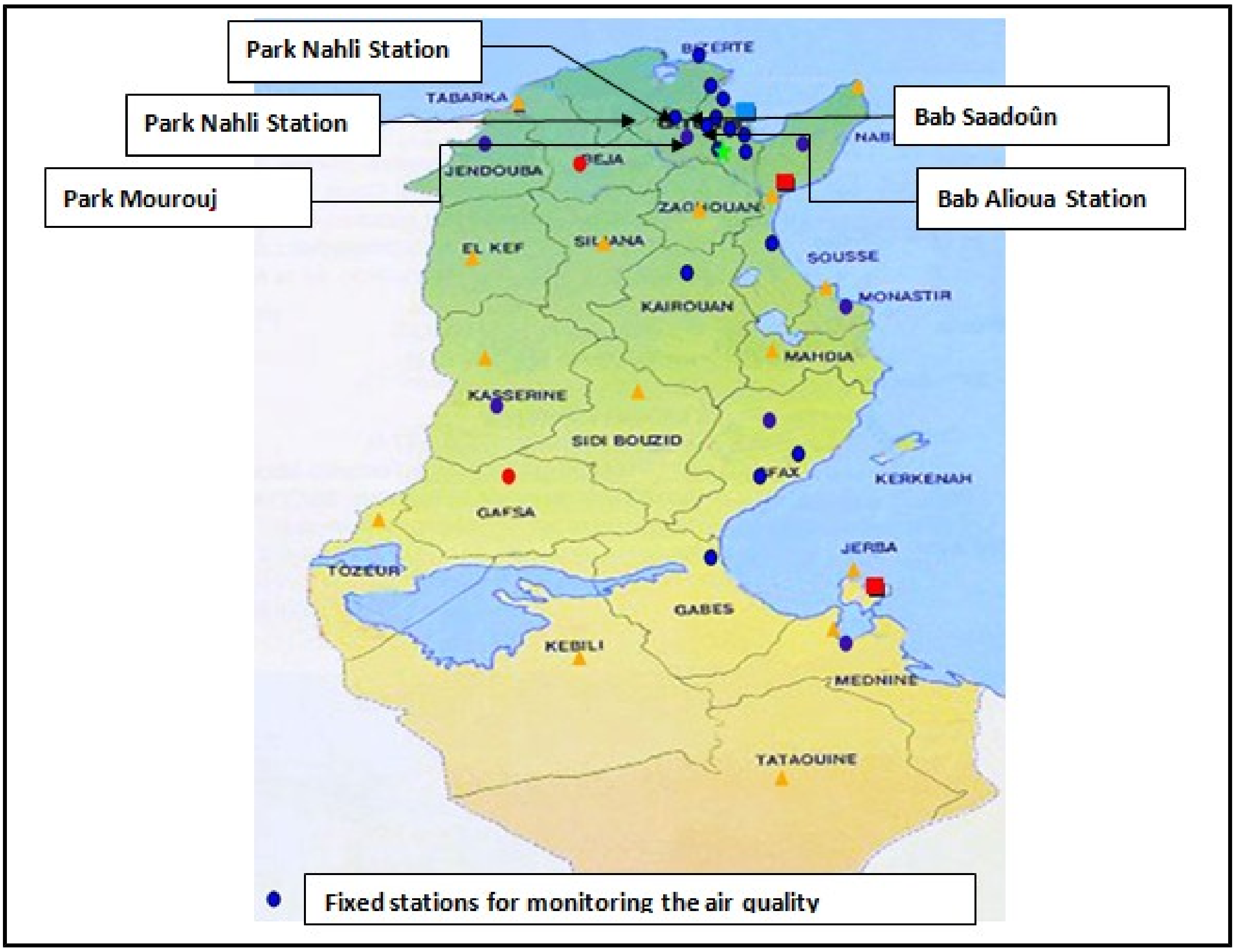

Fig 8. Area study

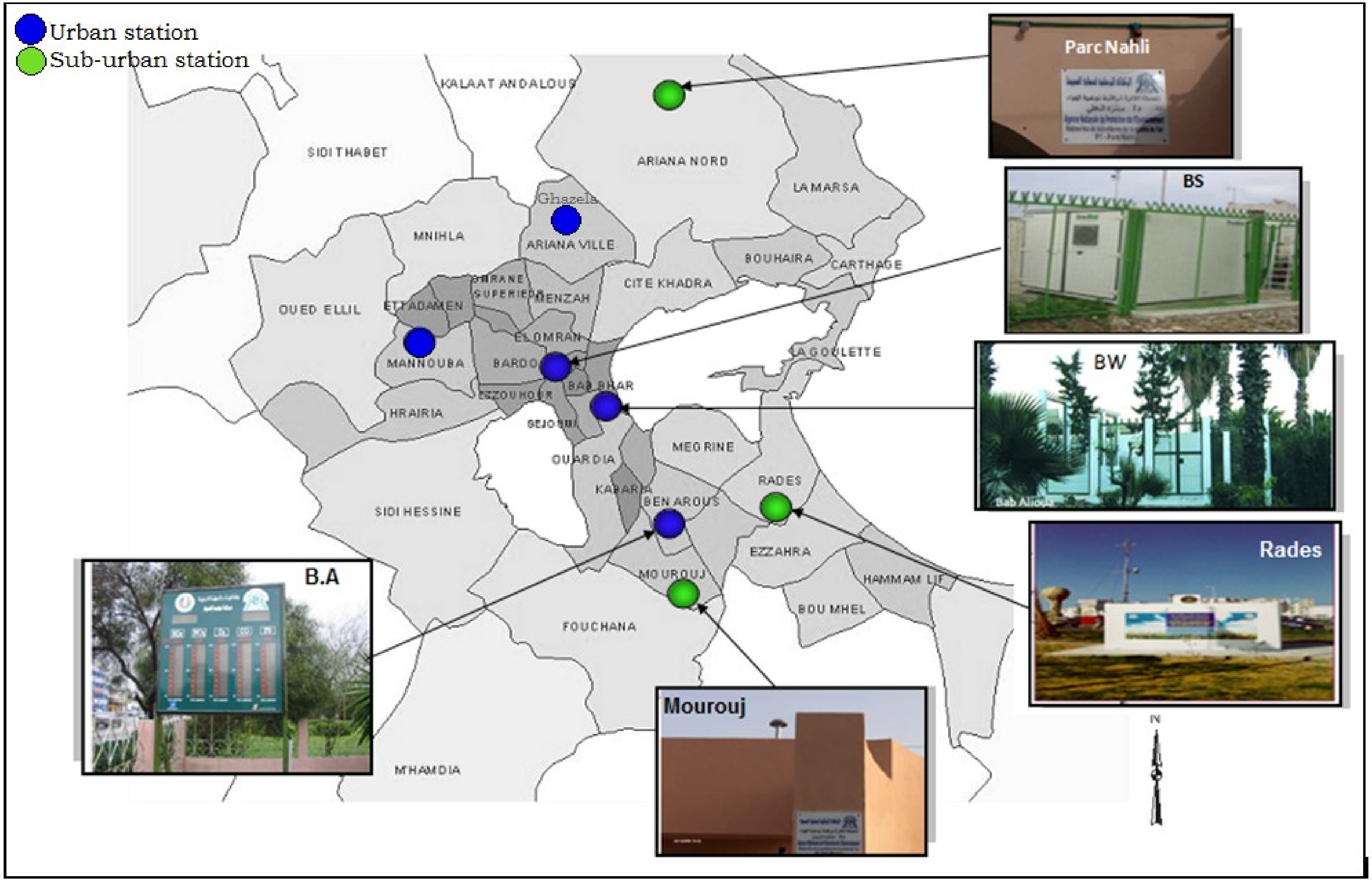

Fig 9. Zoom on study area stations

III. Choice of the study period

The choice of the study period was done according to the availability of pollution data.

The study was conducted over 7 years from January 2003 to December 2010.

Levels of pollutants studied were expressed in µg/m^3. Eight stations were measuring these pollutants in the region of Grand Tunis (Table 2).

Table 3. Typology of monitoring stations of air quality in Greater Tunis

Station	Rades	Ben Arous	Bab Saadoun Tunis	Parc Nahli Ariana	Parc El Mourouj	Bab Aliwa Tunis	Manouba	Ghazela
Typology	urban	Near industrial zone	Near traffic	Suburban	Urban	Near traffic	Near traffic	Urban

We began by collecting raw data from the National Network for Monitoring Air Quality in Excel files. The data were then exported and analyzed using the software R-Cran. R is a computer programming language developed specifically for the purposes of analyzing data (R-project). It is variously described as a statistical system, a system for statistical computation and graphics, and an environment for data analysis and statistics. Its origins go back to innovative developments at Bell Laboratories in the USA during the 1970s, where the language developed was called S. Since that time S has become commercial software and is sold as S-Plus by the Insightful Corporation. S-Plus is highly capable software but is expensive and not widely used by most organizations that this initiative is aimed at.

Over the past 10 years or so an open-source version of S has been developed called R. Unlike some open-source software R is highly developed, highly capable and well established. It is very robust and works on a wide range of platforms (e.g. Windows, Mac, and Linux) [Openair,2011].

One of its strengths is the large and growing community of leading researchers that contribute to its development. Increasingly, leading statisticians and computational scientists choose to publish their work in R; making their work available worldwide and encouraging the adoption and use of innovative methodologies [Openair,2011].

There are numerous reasons why R is a good choice for analyzing and assessing pollutants level data. A few are listed below [Openair,2011]:

- It is free. For this reason, R has become increasingly popular among a wide range of users including universities and businesses.
- It works on several platforms e.g. Windows, Mac OS, and Linux. This makes it very portable and flexible. It is also extremely robust; it is remarkably bug-free and crashes are very rare.
- It has been designed with data analysis in mind to carry out analysis quickly, effectively and reliably.
- The base system offers a very wide range of data analysis and statistical abilities.
- Excellent graphics output that will grace any report. Furthermore, all the default plotting options have been carefully thought out unlike Excel, for example, whose default plotting options are very poor. There are over 2500 packages that offer all kinds of wonderful analysis techniques not found in any other software package.

Unfortunately, data collected from the National Agency of Environmental Protection (ANPE) suffers from several shortcomings. Missing values (Tables 4,5,6,7 and figure 10), also the problem of homogeneity of data with averages sometimes daily and sometimes hourly or four-hourly.

Table 4. Availability Calendar of data in Bab Saadoun station (Gharbi, 2012)

Pollutant Year	NO_2	SO_2	PS
2003	25%	0%	25%
2004	100%	0%	100%
2005	100%	0%	100%
2006	100%	0%	100%
2007	66.6%	0%	0%
2008	16.6%	0%	0%
2009	0%	0%	0%
2010	0%	0%	0%

Table 5. Availability Calendar of data in Bab Aliwa station (Gharbi, 2012)

Pollutant Year	NO_2	SO_2	PS
2003	0%	0%	0%
2004	0%	0%	0%
2005	0%	0%	0%
2006	0%	0%	0%
2007	8.33%	16.6%	16.6%
2008	91.6%	100%	100%
2009	91.6%	91.6%	91.6%
2010	41.6%	58.3%	66.6%

Table 6. Availability Calendar of data in Ghazela station (Gharbi, 2012)

Pollutant Year	NO_2	SO_2	PS
2003	0%	0%	0%
2004	0%	0%	0%
2005	0%	0%	0%
2006	0%	0%	0%
2007	16.6%	16.6%	16.6%
2008	100%	100%	100%
2009	83.3%	100%	100%
2010	83.3%	83.3%	75%

Table 7. Availability Calendar of data in Manouba station (Gharbi, 2012)

Pollutant Year	NO_2	SO_2	PS
2003	0%	0%	0%
2004	0%	0%	0%
2005	0%	0%	0%
2006	0%	0%	0%
2007	8.33%	8.33%	8.33%
2008	100%	100%	91.6%
2009	66.6%	66.6%	66.6%
2010	0%	0%	0%

For Mourouj station, we have data only during year 2010 concerning the three pollutants. The same for Ben Arous station we have data only for year 2010.

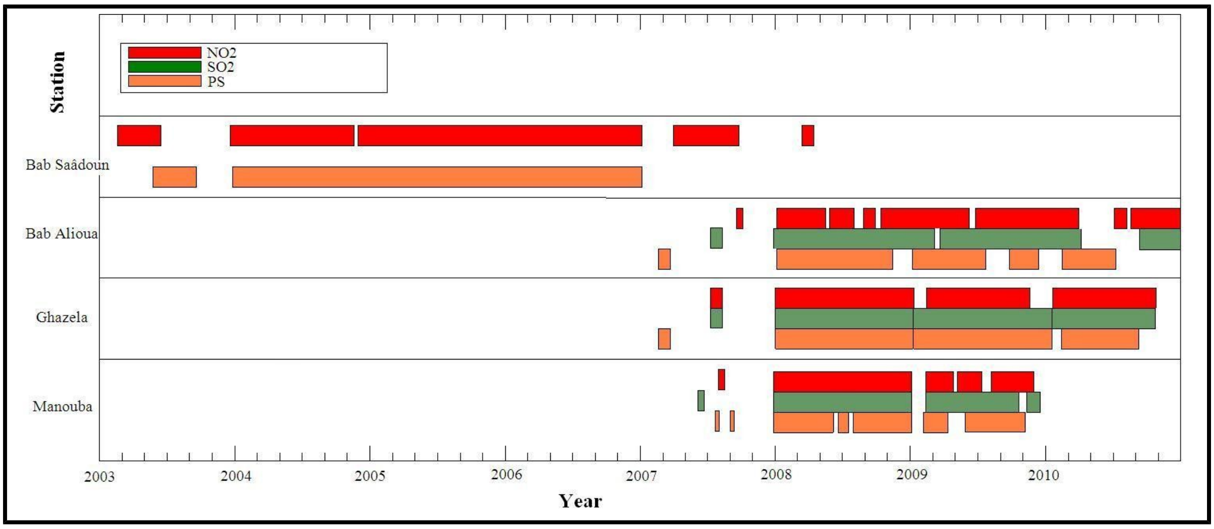

Fig 10. Summary of data availability in considered stations (Gharbi, 2012)

IV. Monitoring air quality methods followed by the National central station

All gas and particulate matter (PS) analyzers and the meteorological sensors are controlled remotely using a data acquisition system ensuring the operation and the control of various devices in an automatic manner and continuous.

This workstation has a transmission system (modem) connected to all cabins and is the NCP (National Central Post Office).

The creation of a database, analyzing and consolidating information above can characterize the evolution of air quality and identify sources of major pollutants.

The NCP is composed of a server, two terminals, modems and three routers to serve as liaison between the server and the mail.

The server calls the post four times a day: 8h, 12h, 16h, and 20h

The analyzers are taking steps every second and when it collects measurements of 10 seconds: the average is taken and sent to the service acquisition measure (SAM) that averages a quarter of an hour and sent to the NCP.

The software that controls the data processing in the NCP is the XR.

Averages collected are processed and displayed in a table; this allows us to show the defects of the station in question. Colors signify the validity of data [RNSQA,2010]:

- Green: usable data
- Violet: maintenance, an analyzer can change a filter when it is saturated, the time it changes is when filter is displayed purple which means that the value recorded during that time is not taken into account.
- Yellow: Calibration or zero air: this is done every 23h or 25h air purified by activated carbon 15 minutes left in the analyzer with a standard deviation of plus or minus 7ppb, then within 15 minutes after it performs SPAN which is the reference value for the following measures and whose margin of error plus or minus 10 ppb.
- Blue: color displayed when exceeding standard deviations.
- Red: invalid value.

V. Architecture of a fixed station

They have the same structure but the head of the analyzer and sampling differ between specific pollutants:

- Head of sampling
- Line Sample Rate of the sampling head up to the analyzer
- An air conditioner to maintain the stable temperature inside the cab
- analyzer specified for each pollutant
- Sensors determining weather conditions:
    - Vane: determines the direction and the wind direction
    - Anemometer: measuring wind speed
    - Radiometer: captures solar radiation and sunshine measure
    - Barometer: measures the pressure inside the cab of the station

VI. Measuring principle

VI.1 Nitrogen oxides (NOx)

The measuring principle is based on chemiluminescence [RNSQA,2010]:

- Chemiluminescence and nitrogen compounds

The principle is based on the chemical reaction between ozone (O_3) and NO. A photomultiplier measures the intensity of the light emitted at a wavelength located in the .(red (1100 nm

NOx phase measures both NO and NO_2 in the sample, while NO phase measures only NO. NO_2 concentration is obtained by subtracting the signal NO of the signal NOx.

- Signal processing

The sample gas is mixed with O_3 to produce a reliable light. This light is converted into an electrical signal by the photomultiplier PM. The emitted light being periodically blocked by a mechanical blade (chopper), the output signal of PM is a sinusoidal signal. The signal amplitude is proportional to the concentration of the selected gas by the solenoid valves. The continuous signal is integrated by an analogue filter and then converted by an AD converter of the microprocessor board.

- Calculation of the concentration NO_2

The analyzer performs a direct measurement of NO and NOx (after conversion of NOx as NO) in alternative measurement sequences. NO_2 is not directly measured, but calculated as the difference between the NOx and NO.

VI.2 Sulfur dioxides (SO_2)

The measuring principle is based on the UV fluorescence. UV fluorescence analyzers use a source (zinc vapor lamp) of wavelength region of 215 nm, which has the property of exciting the molecule SO_2 [RNSQA,2010]:

Deactivating the molecule SO_2 can be done using two mechanisms:

- The first is the transfer of energy between molecules during collisions, it is a process called "non-irradiative".

- The second mechanism is a dissipation of energy by emitting electromagnetic radiation, it is a process called "irradiative".

Measurement at 90 ° emission is proportional to the concentration of SO_2 contained in a measuring vat.

VI.3 Particulates (PS)

The measurement is based on the principle of the beta gauge, consisting of a radioactive source (β soft rays) and a Geiger-Müller.

A known volume of air is sucked the particles are deposited on a glass fiber filter, the filter located between the source and the Geiger beta is subject to β-ray (The same operation is performed in advance when the filter blank is can then be measured the absorption of the filter). The rays of low energy are absorbed by the material by collision; the absorption is proportional to the mass of material encountered regardless of the physical and chemical nature of the latter [RNSQA,2010].

VII. Use of data

- Choice of dates: choice of the nature of the medium: a quarter of an hour, hourly, daily, monthly, annual
- Rates Validity: 75% average hourly averages 3 is valid if a quarter of an hour are exploitable
- Averaging: You can also perform calculations predefined as:
  - The extraction of the 10-maximum values
  - The class-winds
  - Threshold and standard deviation: The threshold is set by users
  - Wind rose and pollution

The particularity of this report is the use of new techniques such as CART statistical model to better interpret the results of the analysis. This model is primarily used to classify cases the most homogeneous among themselves of point of view predefined objective.

The box mustache is a simple graphical tool, accurate and efficient briefly displays the dispersion of a series of observations. The graphical representation includes, among other various indicators of position (1st and 3rd quartile, median, ..) as shown in the following figure [RNSQA,2010]:

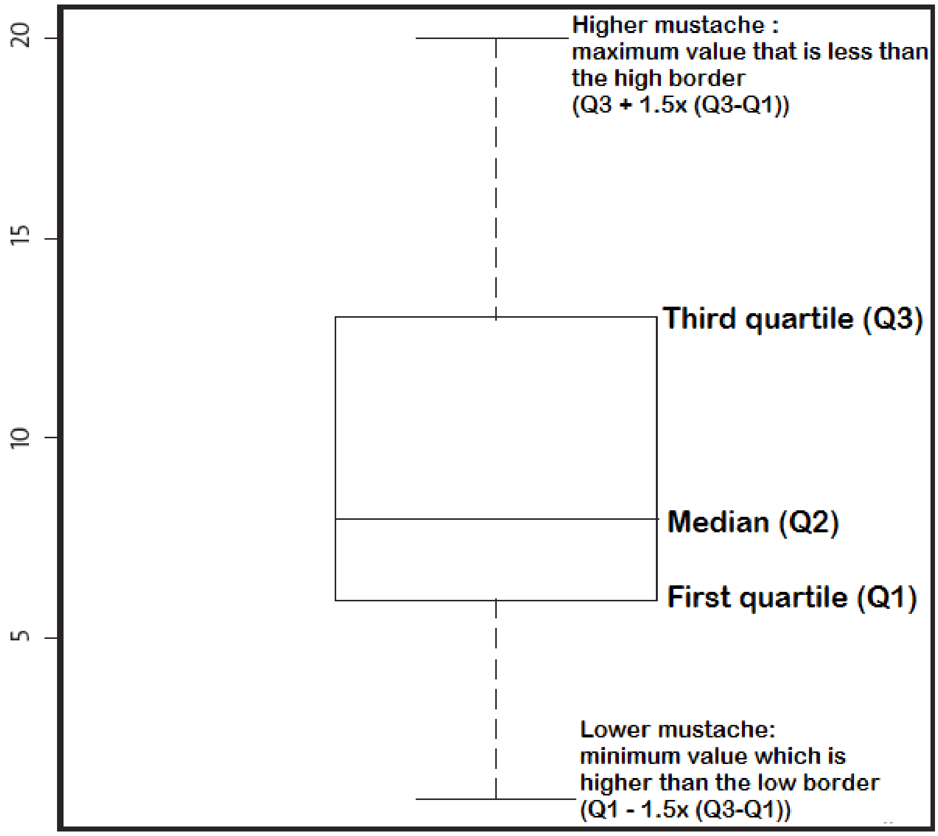

Fig 11. Box plot generated by the software R (RNSQA,2010)

Part IV: Results and discussion

I. Introduction

In this section, we present a preliminary quantitative approach development of air quality with the main results obtained in the different stations monitoring air quality as well as evolution of pollutants and situations by the standards.

II. Definitions

Typical day curve or daily cycle: The graph of the typical day summaries statistics that show the average behavior of a pollutant during a day (24 hours).

Curve of typical day is a series of 24 averages. Each value (e.g. 13 to 14h) is the average of all hourly averages 13 to 14h recorded daily throughout the period.

Typical week curve: The curve summaries statistics that show the average behavior of a pollutant during a week (7 days).

The typical week curve represents a series of seven averages (Monday to Sunday). Each value (e.g. Monday) is the average of all daily medium recorded on Mondays during the period concerned.

Monthly evolution: The curve of the monthly evolution highlights trends of monthly averages of pollutant throughout the year. This curve focuses on the behavior of pollutants according to the seasons.

Urban station: Means a station measuring air quality in an urban center located away from point sources (radius of action 2 km). The emissions come from inside this area. The objective of such station is monitoring the average exposure level of the population to air pollution in urban centers.

Suburban station: Means a station measuring air quality at the periphery of an urban center (radius of action 5 km). The emissions (transport, heating, industry) come from inside and / or outside of this area. They help to better understand the phenomena related to the secondary pollution like ozone for example.

Station near traffic: such station aims to monitor concentrations level of air pollutants measured in areas of the maximum exposure to a road infrastructure.

Industrial Station: its objective is monitoring concentrations level of air pollutants induced by industrial activity.

III. Spatial analysis

This phase allows to compare the results of the measurements recorded between different stations studied of the Great Tunis, and to evaluate the level pollution of pollutants vis-à-vis the Tunisian standard NT.106.04. The choice of years of study for every case is based on the availability of data for a typical and meaningful study.

III.1 Nitrogen dioxides (NO_2)

The table below summarizes standards taken to limit air pollution by NO_2.

Table 8. Tunisian and WHO standards for NO_2 (Gharbi,2012)

	Tunisian standards (µg/m³)			
NO_2	**guideline values**	**limit values**	**Authorization to exceed**	**WHO**
Average 1h	**400**	**660**	**1/30 days**	**200**

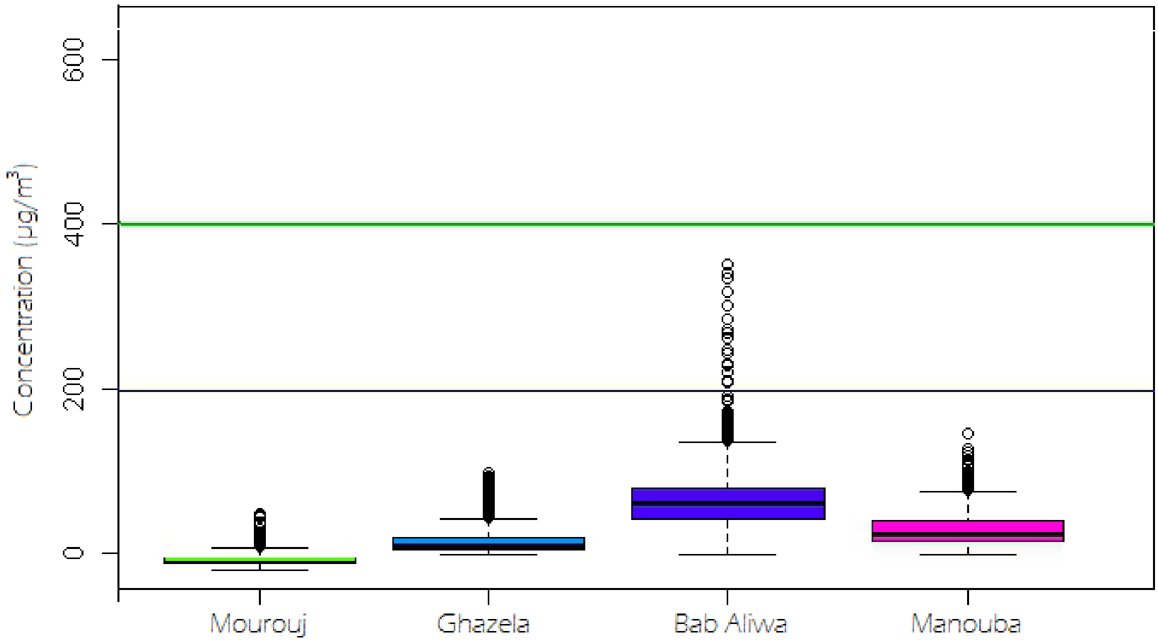

Fig 12. Spatial evolution of NO_2 Year 2010

The curve above is the box plot corresponding to concentration evolution of nitrogen dioxide in four stations: Mourouj, Ghazela, Bab Aliwa and Manouba during 2010. We don't note any exceedance of Tunisian standards but there is exceedance of the WHO standards.

The graph below shows the maximum hourly nitrogen dioxide in the stations of the network that means the average of the maximum concentrations recorded during the year 2010. The recorded values are generally below the limit values and guide relative to nitrogen dioxide standard NT 106.04.

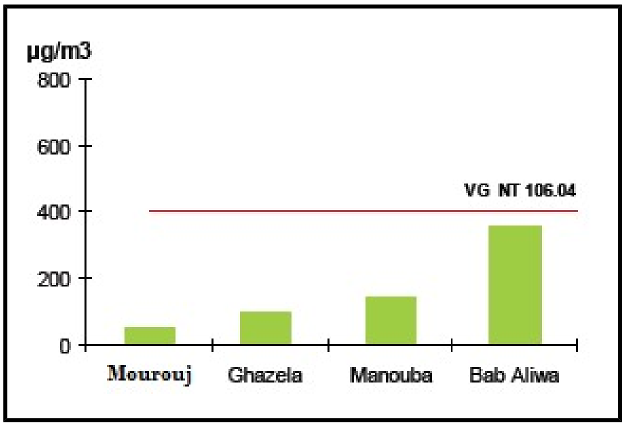

Fig 13. Maximum hourly nitrogen dioxide in studied stations, year 2010 (Gharbi,2012)

The following graph shows the correlation between ozone and nitrogen oxides during a typical day of December 2010. During the first hours of the day the concentrations of nitrogen dioxide are rising due to the resumption of traffic, but these concentrations are lower and later give way to higher concentrations of ozone that is formed due to secondary reactions under the effect of the heat of the day.

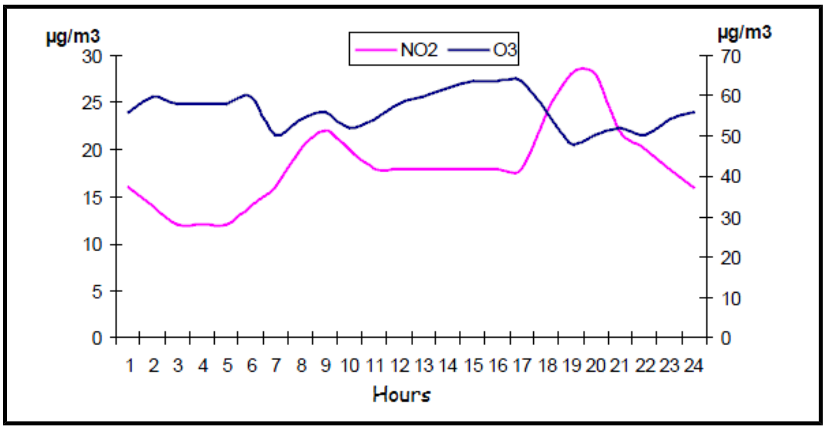

Fig 14. Correlation between ozone and nitrogen oxides December 2004 (Gharbi,2012)

III.2 Sulfur dioxide (SO_2)

The table below summarizes standards taken to limit air pollution by SO_2.

Table 9. Tunisian and WHO standards for SO_2 (Gharbi,2012)

	Tunisian standards (µg/c)			
SO_2	**guideline values**	**limit values**	**Authorization to exceed**	**WHO**

Average 24 h	**225**	**365**	**1/year**	**20**

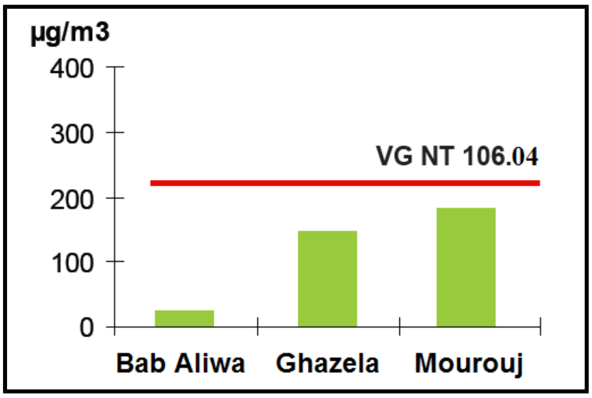

Fig 15. Maximum daily sulfur dioxide concentration in some stations (Gharbi,2012)

The curve below shows the maximum daily sulfur dioxide recorded in some of the major network stations in Tunis.

The highest concentration is observed at Station Park Mourouj without exceeding the limit value of the standard NT106.04 related to sulfur dioxide.

Ghazela station recorded relatively low concentrations in the year 2010 with a little exceedance of the guideline value.

The Bab Aliwa station near traffic and with urban background recorded no exceedance and with relatively low concentrations compared to other stations, explained by the fact that the traffic does not cause emissions of sulfur dioxide.

III.3 Suspended particles PS

The table below summarizes standards taken to limit air pollution by PS.

Table 10. Tunisian and WHO standards for PS (Gharbi,2012)

	Tunisian standards ($\mu g/m^3$)			
PS	**guideline values**	**limit values**	**Authorization to exceed**	**WHO**
Average 24 h	**120**	**260**	**1/ year**	**50**

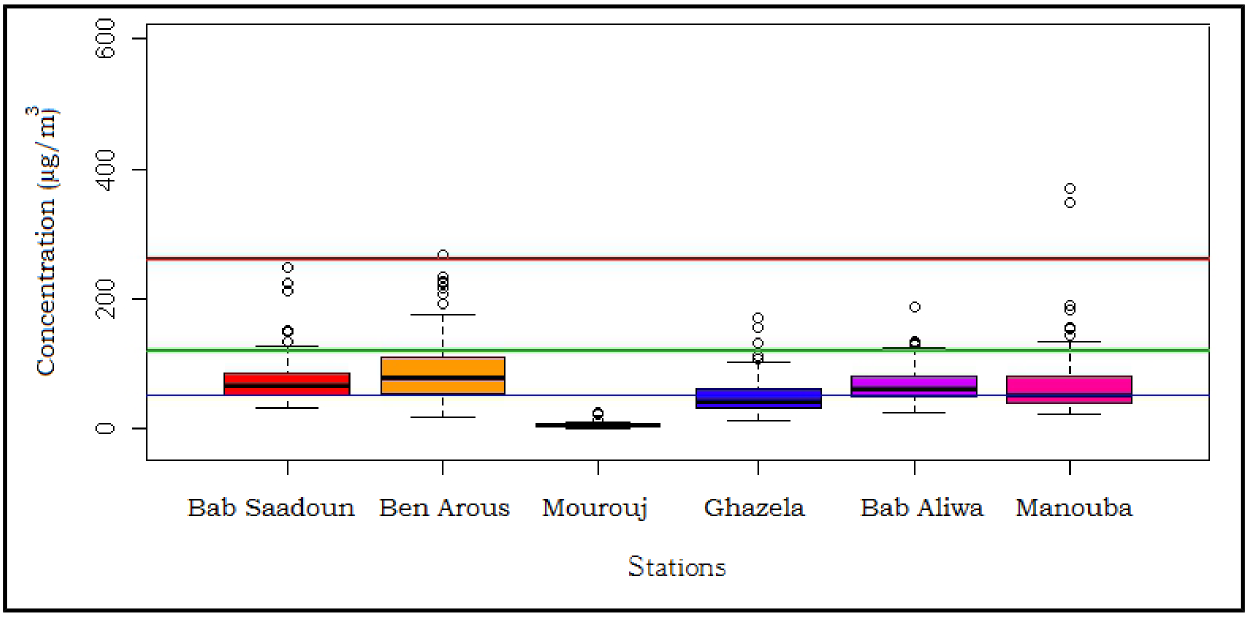

Fig 16. Spatial evolution of dusts 2010 (Gharbi,2012)

The previous graph shows the evolution of the concentration of particles in the different stations of the network. The highest concentrations are recorded at the station of Ben Arous which is an industrial station. However, the lowest one are recorded at Mourouj which is a sub-urban station.

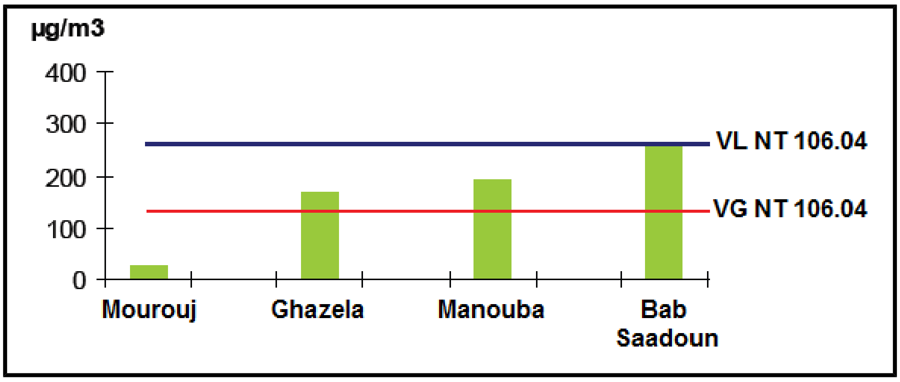

Fig 17. Maximum daily of suspended particles 2010 (Gharbi,2012)

The above curve shows the maximum daily of suspended particles in different network stations during the year 2010. Exceedances of limit values and guide values are recorded in different stations. The origins of these particles is different from one site to the other natural or anthropogenic or both.

IV. Temporal analysis

IV.1 Nitrogen Dioxides (NO_2)

- **Monthly evolution**

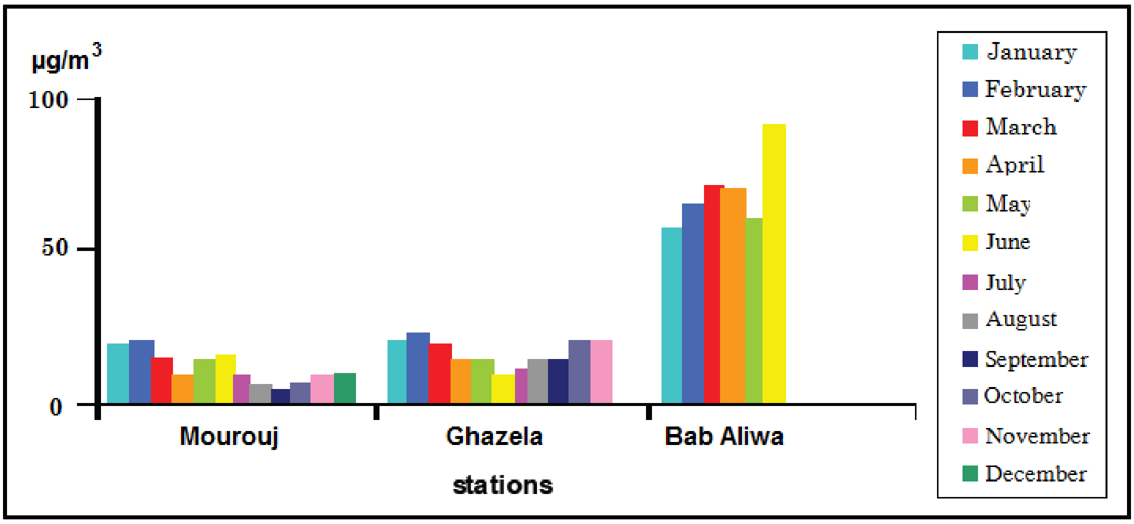

Fig 18. Monthly evolution of nitrogen dioxide in 2010 (Gharbi,2012)

We present by the above graph the evolution of the monthly average of nitrogen dioxide during 2010. Nitrogen dioxide is monitored in three stations measuring air quality located in Bab Aliwa, Ghazela and Mourouj Park.

At Mourouj and Ghazela, the highest averages were marked during the month of February.This may be explained by a remarkable increase in traffic density during this period, and school activities.

At Bab Aliwa, the highest averages were recorded during June. The lower concentrations of nitrogen dioxide, in 2010 were recorded at the Mourouj station which is suburban.

For the Bab Saadoun station, statistics of the maximum values measured on 2007 for nitrogen dioxide indicate that all results meet the standards with a small increase for the month of November as shown in the following graph.

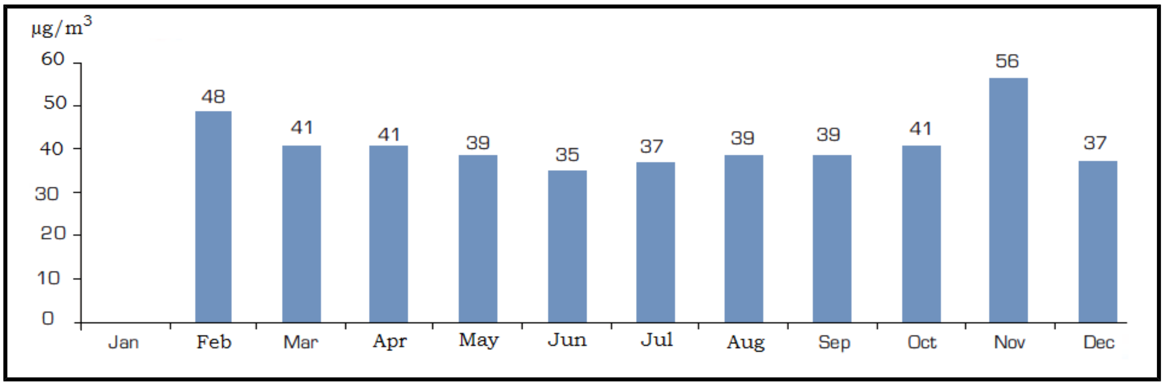

Fig 19. Maximum nitrogen dioxide recorded at Bab Saadoun for 2007

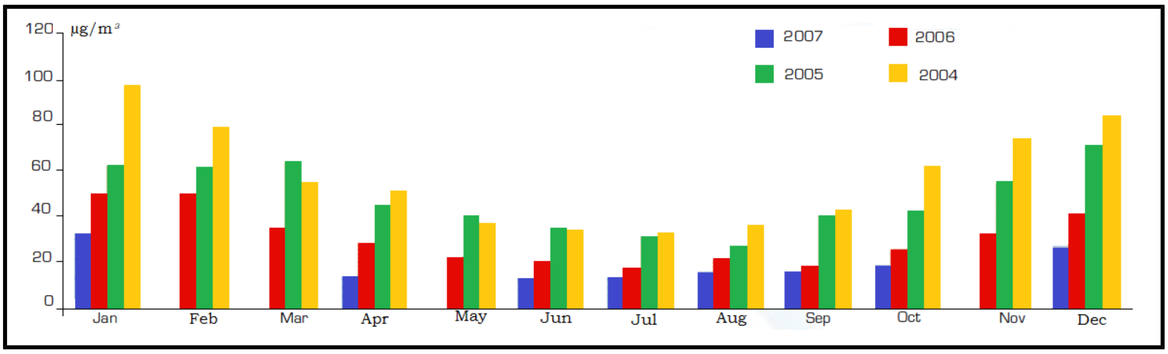

Fig 20. Comparison of mounthly average nitrogen dioxide between 2004 and 2007 in Bab Saadoun (Gharbi,2012)

The histogram above shows that 84% of the average nitrogen dioxide evolves in order of decreasing during the period between 2004 and 2007. The highest values were observed during the months of January and February.

A classic seasonal variation concentrations of nitrogen oxide was so detected: the highest levels are observed during the winter season (October-February) against by the summer season (March-September) is characterized by the presence of low concentration.

This seasonal concentrations of nitrogen dioxides, is the result of several factors, including the intensity of emission sources which is higher in winter than in summer due to heavy traffic in winter and decrease in summer explained by the summer holidays.

- **Weekly evolution**

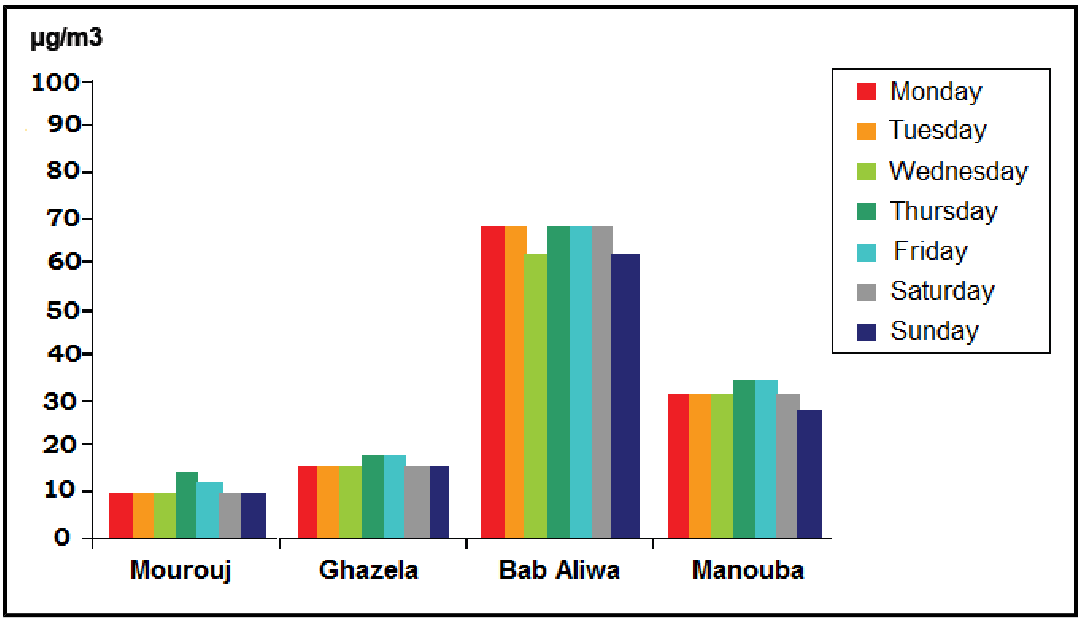

Fig 21. Weekly evolution of nitrogen dioxide's concentrations in some stations (Gharbi,2012)

The figure above shows the evolution of the typical week of nitrogen dioxide during the year 2010, obtained from the data collected.

An increase in NO_2 concentrations on Monday preceded by a gradual decline from Friday until the end of the week, this amounts to the strong contribution of traffic to the emission of nitrogen oxides in the air.

We thus note that stations near Traffic such as Bab Aliwa are most affected by these significant changes in the concentrations of nitrogen dioxide during the week. Mondays, concentrations are highest, due to a strong recovery of human activities and subsequently the traffic in that day.

- **Hourly evolution**

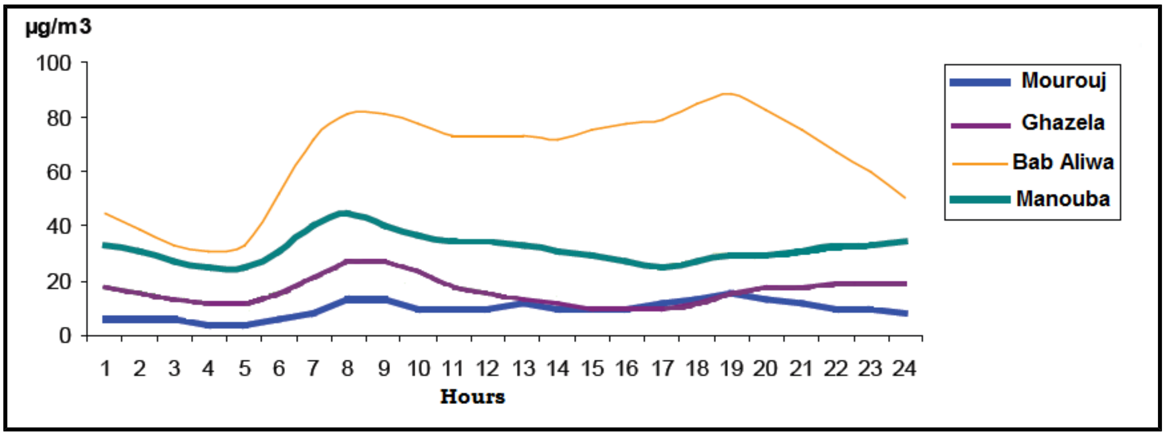

Fig 22. Hourly evolution nitrogen dioxide in some stations 2010

The figure above presents the average daily profiles of nitrogen dioxide obtained from available day's measurement during 2010.

Peak hours correspond to elevated concentrations of nitrogen dioxide in all studied regions. NO_2 is a secondary pollutant, found in relatively higher concentrations near traffic areas, such as Bab Aliwa and in city centers.

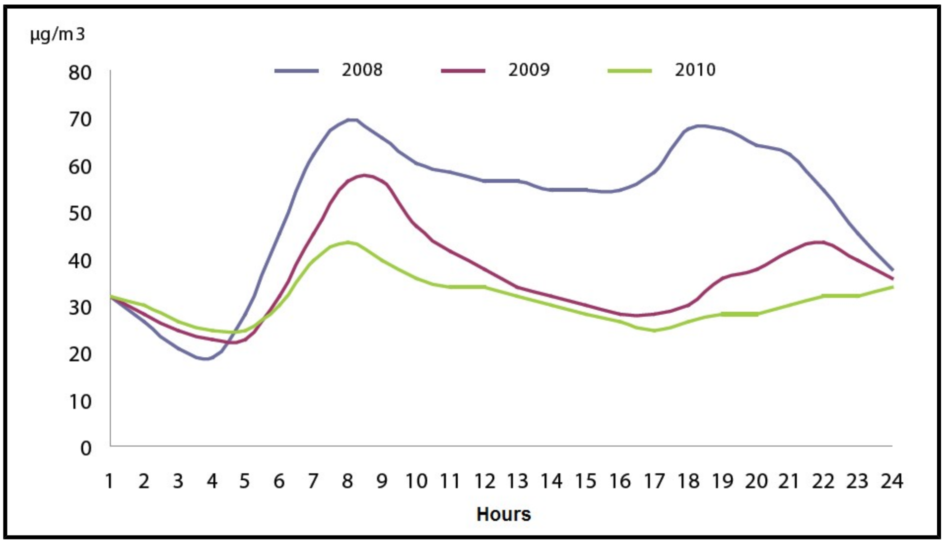

Fig 23. Daily profile's evolution of nitrogen dioxide in Bab Aliwa 2008-2010

Emissions of nitrogen dioxide in Bab Aliwa station between 2008 and 2009, as shown in the graph above, keep almost the same evolution over the three years with a remarkable increase during 2010. Concentrations are high during the day, explained by a high intensity of traffic in this urban area and then a gradual decline in the evening until the early hours of the day when human activities resume.

IV.2 Sulfur dioxide (SO_2)

- **Monthly evolution**

Measurements of sulfur dioxide in Manouba (urban station) for the year 2008 are characterized by low concentrations. However, from April until October, SO_2 concentrations in Manouba have experienced an increase, without any exceedance of the limit or guideline value (figure 24).

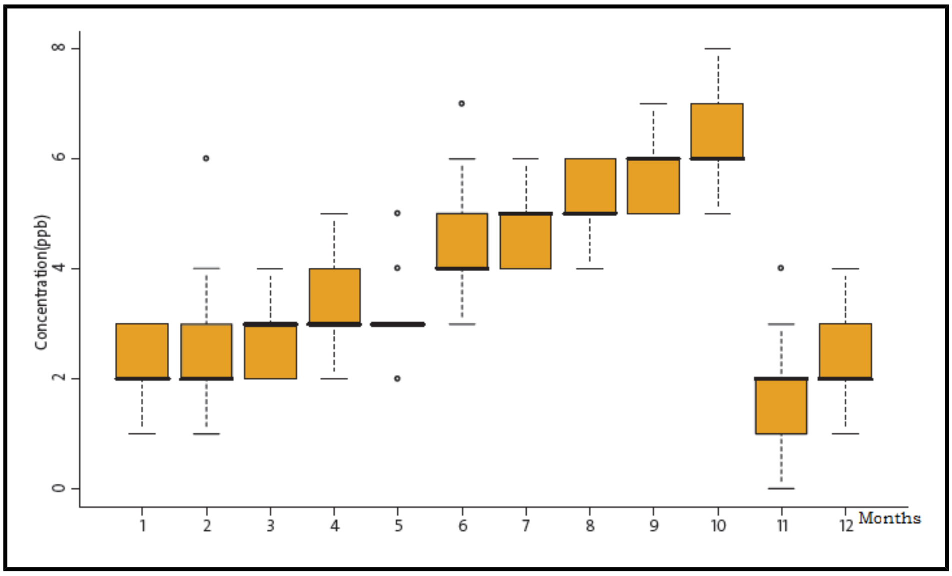

Fig 24. Evolution of sulfur dioxide in Manouba for 2008 (Gharbi,2012)

In Bab Aliwa, the months of August and September marked a particularity vis-a-vis current perspective values observed for SO_2 values observed in Bab Aliwa are between 2 and 4 ppb (respectively 5.24 and 10.48 µg/m^3) for the month of August, a decrease of 2 ppb (5.24 µg/m^3) is observed.

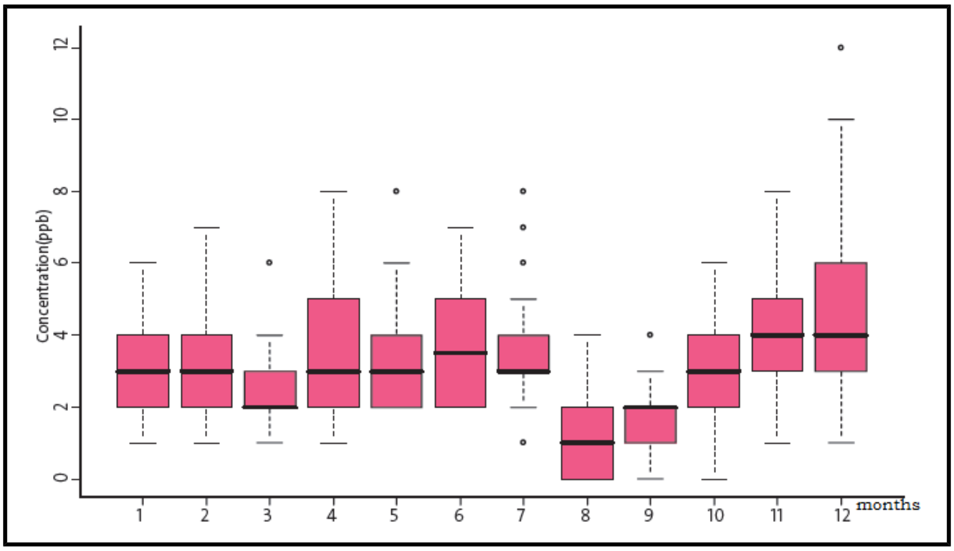

Fig 25. Evolution of sulfur dioxide in Bab Aliwa for 2008 (Gharbi,2012)

In Ghazela, the average SO_2 concentrations were 0 ppb.

Indeed, the lowest values of Tunis stations are recorded at this station.

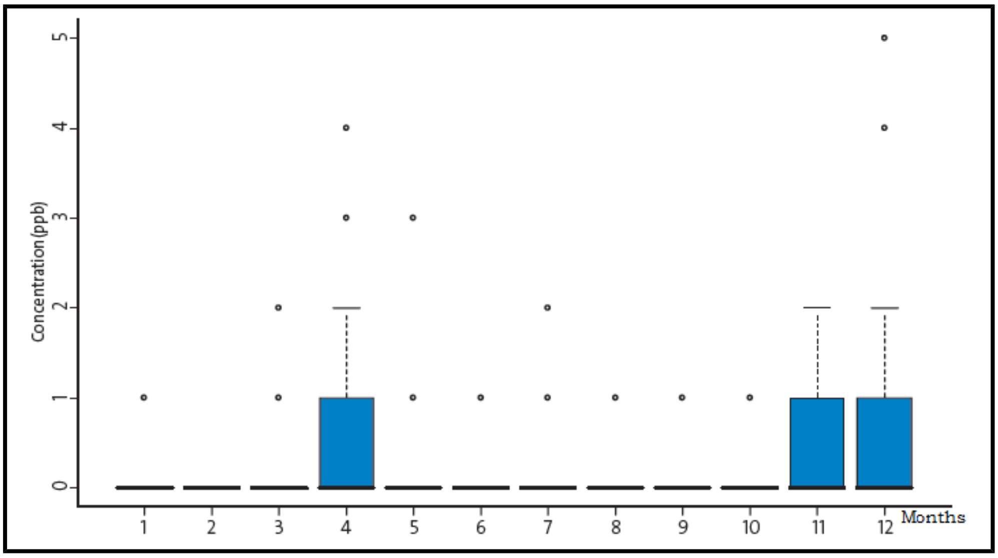

Fig 26. Evolution of sulfur dioxide in Ghazela for 2008 (Gharbi,2012)

- **Hourly evolution**

From statistics, we find that the day in Manouba is characterized by three main phases according to the values observed in SO_2

- Phase 1: from midnight to 6: 30 h average (SO_2) = 3 ppb =7.86 µg/m^3

- Phase 2: 6: 30 am to 15: 30 h on average (SO_2) = 5 ppb = 13.1 µg/m^3
- Phase 3: the rest of the day on average (SO_2) = 3.5 ppb = 9.17 µg/m^3.

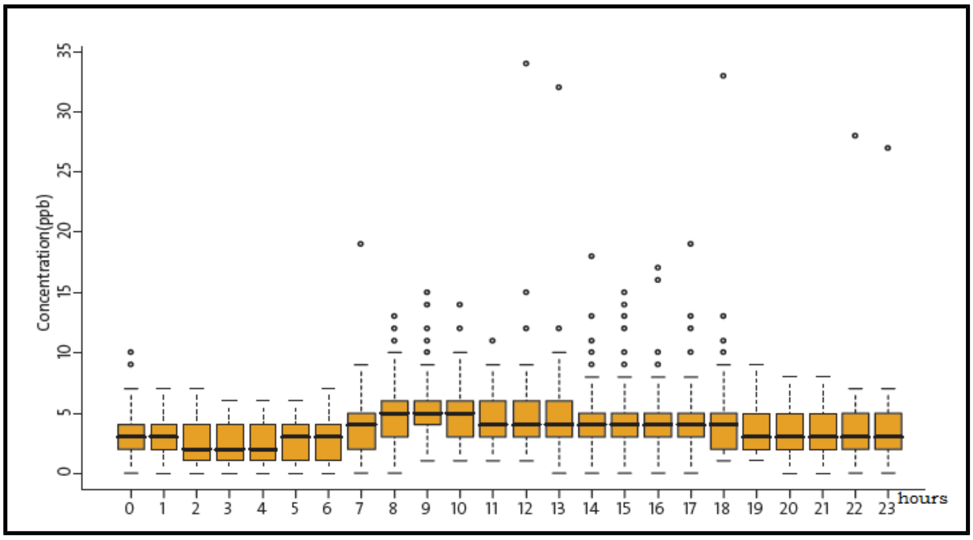

Fig 27. Hourly evolution of sulfur dioxide in Manouba 2008 (Gharbi,2012)

Using statistics, we find that the day in is divided Bab Aliwa into three main phases

- Phase 1: from midnight to 6: 30 h average (SO_2) = 1 ppb = 2.62 µg/m^3
- Phase 2: 6: 30 am to 20: 30 h on average (SO_2) = 4.3 ppb = 11.26 µg/m^3
- Phase 3: the rest of the day on average (SO_2) = 2.6 ppb = 6.812 µg/m^3.

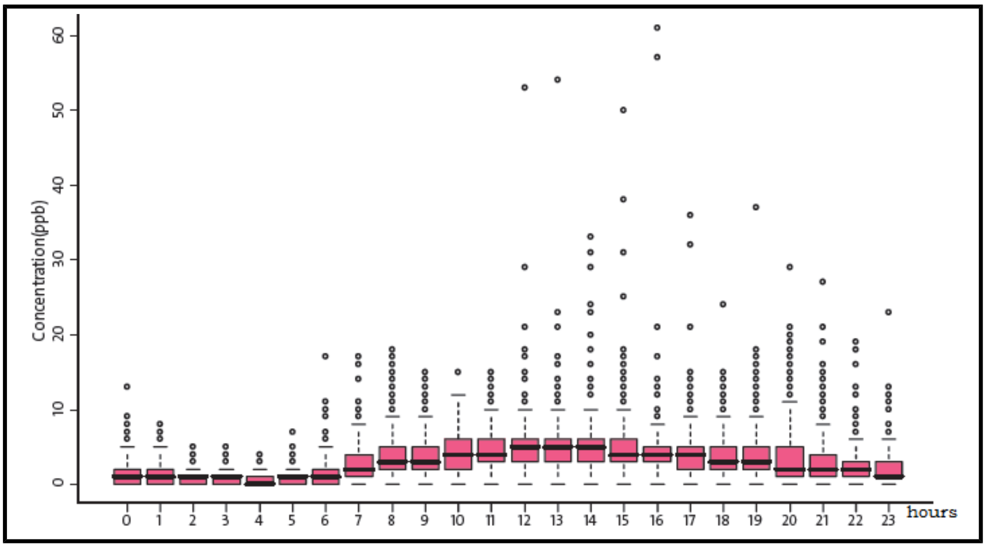

Fig 28. Hourly evolution of sulfur dioxide in Bab Aliwa 2008 (Gharbi,2012)

Using statistics, we find that the day in Ghazela is distributed mainly in two phases point of view the observed values of SO_2.

Phase 1: 0:00 to 7:30 pm in average (SO_2) = 0.07 ppb = 0.183 µg/m^3.

Phase 2: The rest of the day on average (SO_2) = 0.42 ppb = 1.1 µg/m^3.

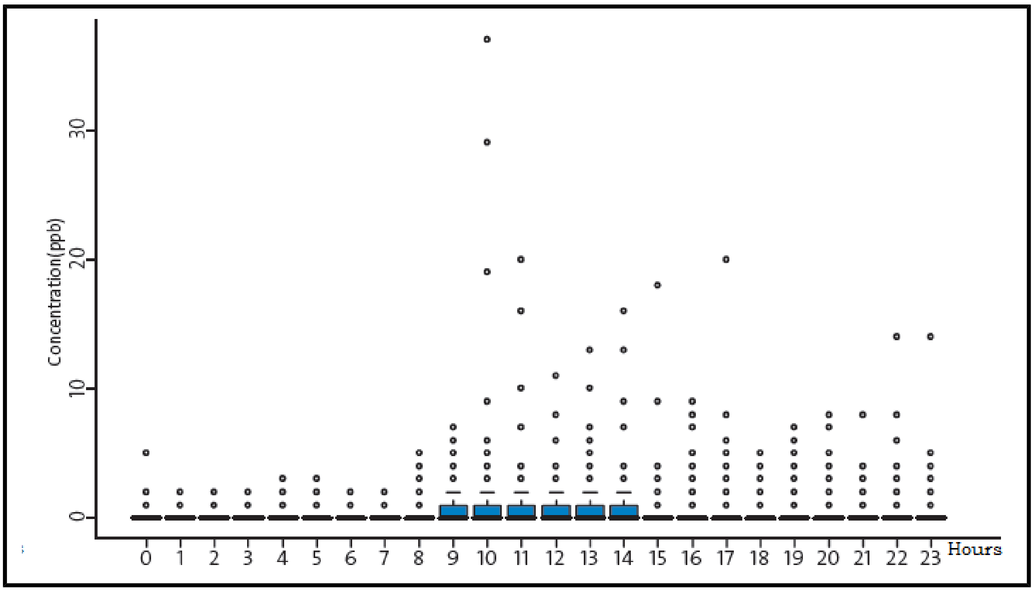

Fig 29. Hourly evolution of sulfur dioxide in Ghazela 2008 (Gharbi,2012)

IV.3 Suspended particles (PS)

- **Monthly evolution**

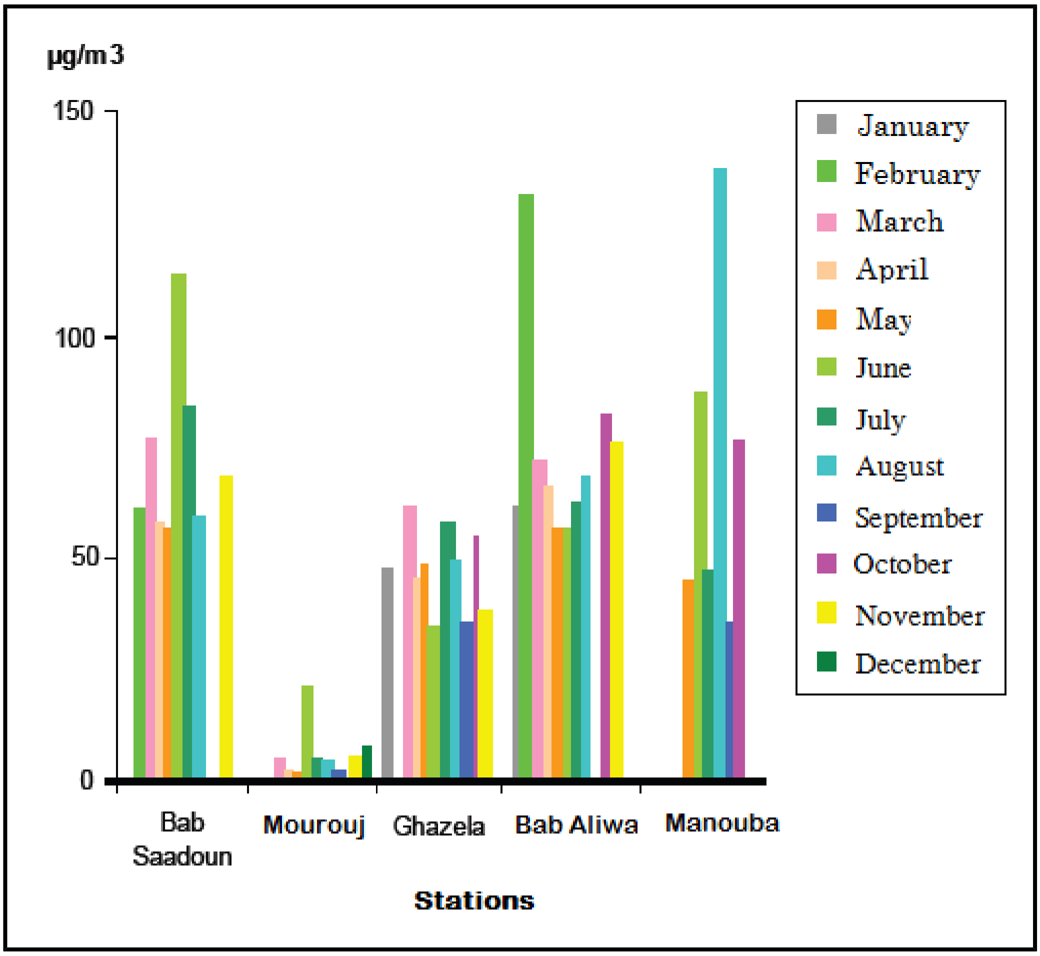

Fig 30. Monthly evolution of dust in some stations year 2010 (Gharbi,2012)

The graph above shows the monthly evolution of dust (PS) in regions where we have enough available data of measure, and during the year 2010.

In Bab Saadoun and Bab Aliwa, February is characterized by the highest concentrations of dusts it's certainly due to high urban traffic activities.

For Manouba, August records the highest concentrations.

Mourouj has lower concentrations throughout the year 2010 compared to other regions because it's a sub-urban station.

The variation of the concentration of suspended particles also follows a seasonal classic variation: the highest levels are observed during the winter season (October-February) against by the summer season (March-September) is characterized by the presence of low stable concentrations (at 70 µg/m^3) as shown in the following figure**.**

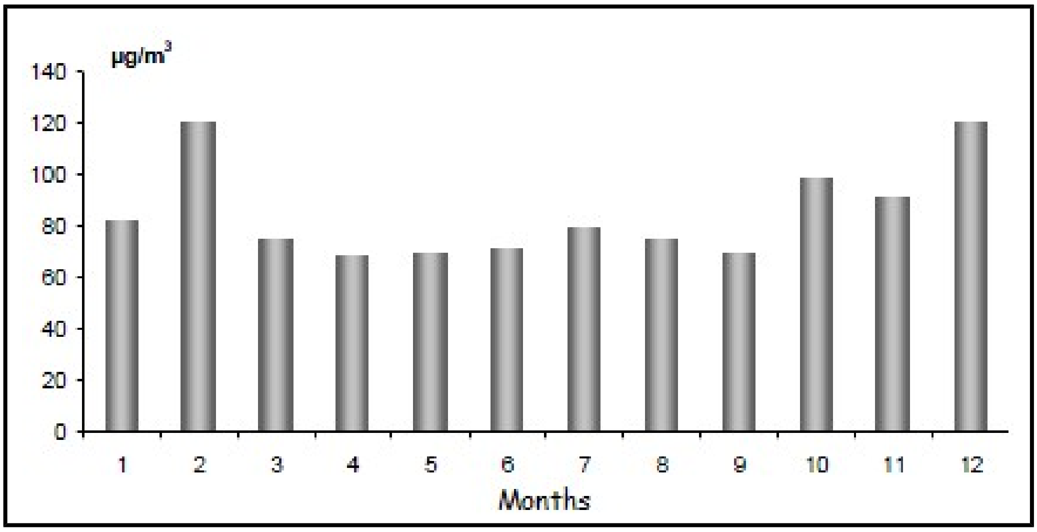

Fig 31. Monthly evolution of PS concentrations in Bab Saadoun station 2004 (Gharbi,2012)

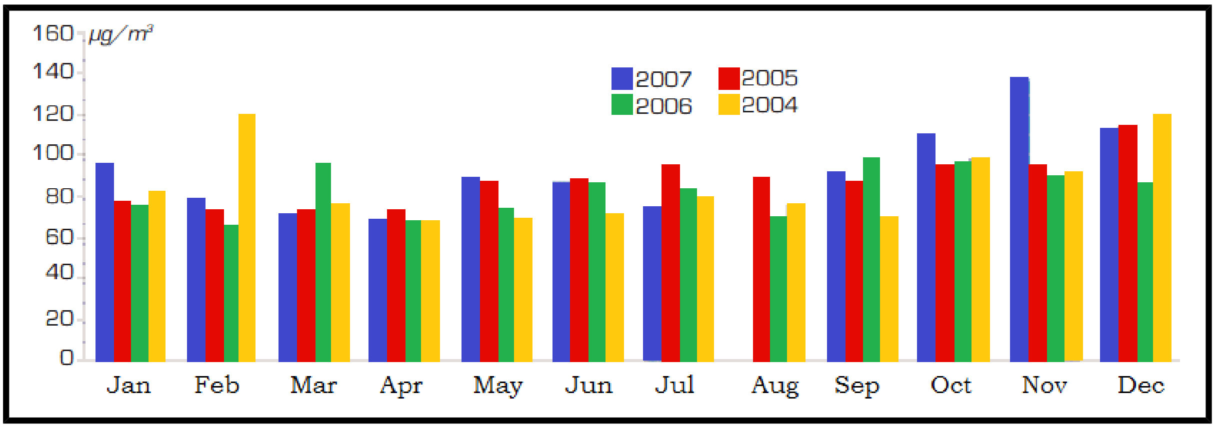

Fig 32. Comparison of suspended particulates concentrations averages between 2004 and 2007 in Bab Saadoun station (Gharbi,2012)

Averages recorded during these four years are basically the same according to the season with two peaks: the first 120 µg/m³ for February in the year 2004 and the second 132 µg/m³ in November for 2007 so there is two exceedances of Tunisian Standards and exceedances of WHO standards (50µg/m³) during every month of these years as shown in the previous graph.

- **Weekly evolution**

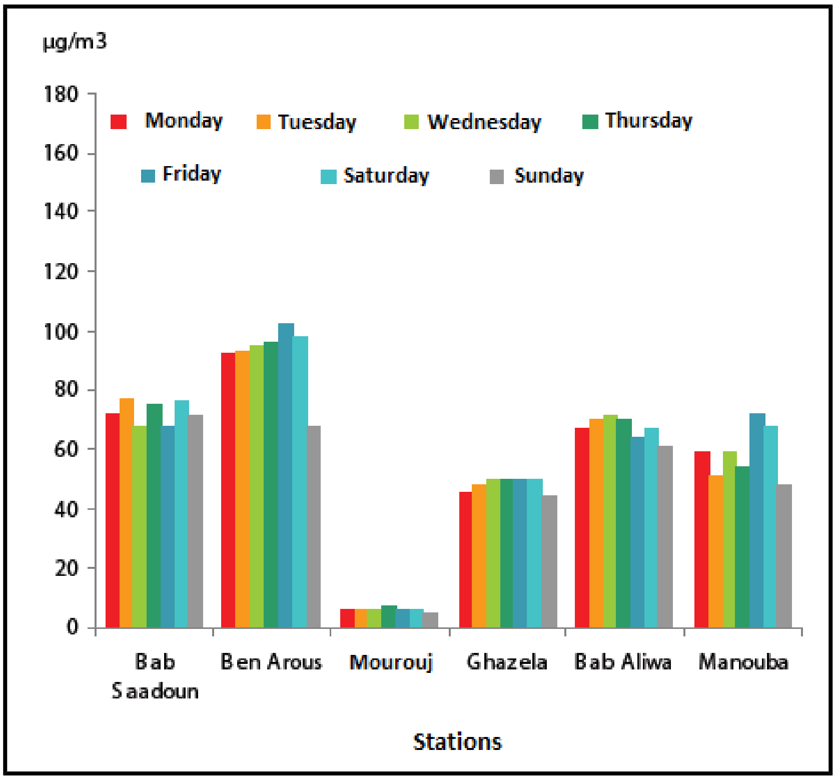

Fig 33. Weekly Evolution of dust in some stations in 2010 (Gharbi,2012)

The graph above summarizes the weekly evolution of dust during the year 2010 in the areas of study. A remarkable decrease in PS concentrations is observed on Sunday compared to other days of the week this is due to a remarkable decrease of human activities on the weekends, such as road traffic and residual activities.

- **Hourly evolution**

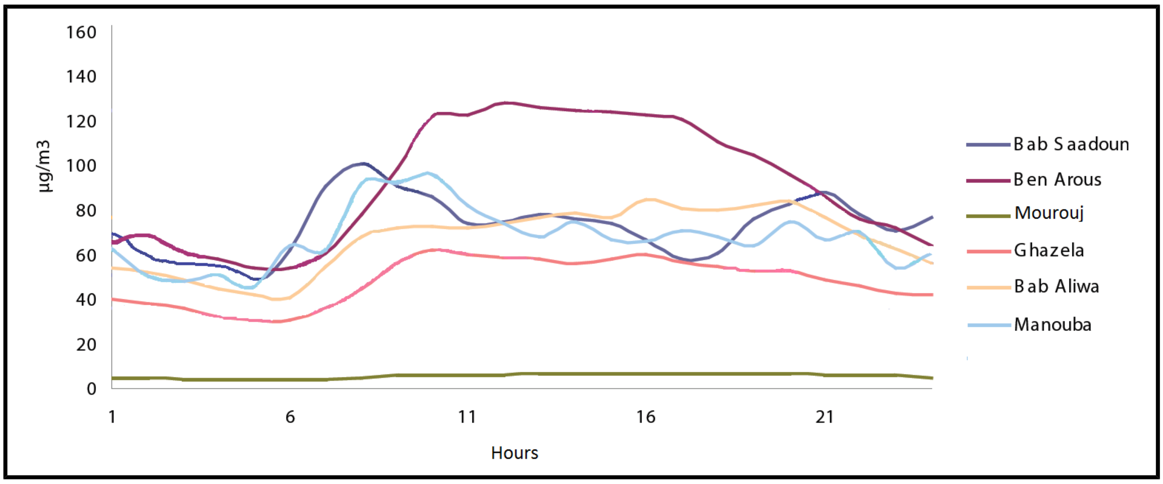

Fig 34. Daily profiles of the dust in 2010 (Gharbi,2012)

The daily profiles of dust smaller than 10 microns (PM10) observed by the stations studied during 2010 are grouped in the graph below.

It is from 7 am that PM10 concentrations begin to rise until the night and with much lower concentrations in the early morning.

V. Influence of meteorological parameters

V.1 Speed and Direction of wind

Movement of air masses along the coast have a significant impact on the level and nature of pollution observed on the ground.

The wind whose speed and direction depend on the horizontal and vertical gradients of the temperature in the atmosphere, ensures generally suitable dispersion of pollutants.

But in certain circumstances mainly in autumn and winter, anticyclones can be formed and move slowly, and calm or persistent temperature inversions can be installed. These phenomena of calm and atmospheric stability or inversion temperatures are, therefore, of considerable importance and should be carefully pursued.

These are key factors explaining the dispersion of pollutant emissions. In fact, the wind comes by its direction to guide the smoke and by its speed to dilute and lead emissions.

Pollutant dispersion increases with speed and wind turbulence. In contrast, when the winds are light, the weight of the influence of local terrain is strong and will appear breezes thermal contrasts [El Melki,2007].

- **Nitrogen Dioxides (**NO_2**)**

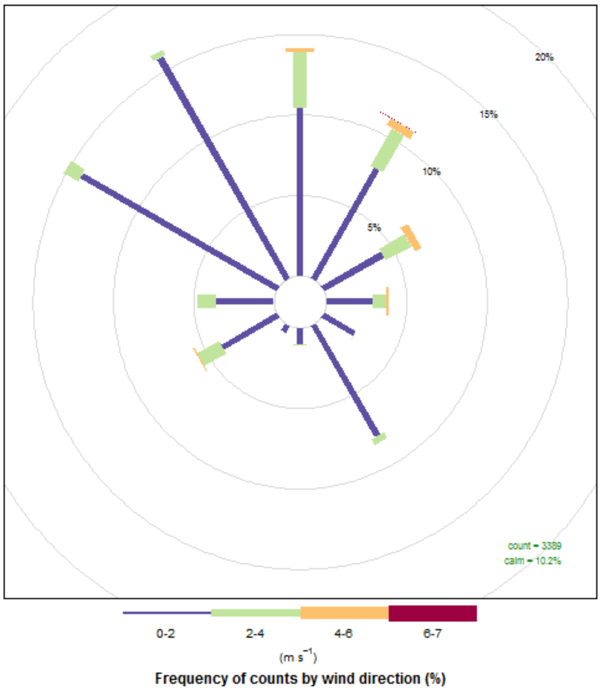

Fig 35. Wind rose in Bab Aliwa 2008 (Gharbi,2012)

The figure below shows the wind rose during 2008 in Bab Aliwa the prevailing wind direction is north-east with a speed of 6 to 7 m / s.

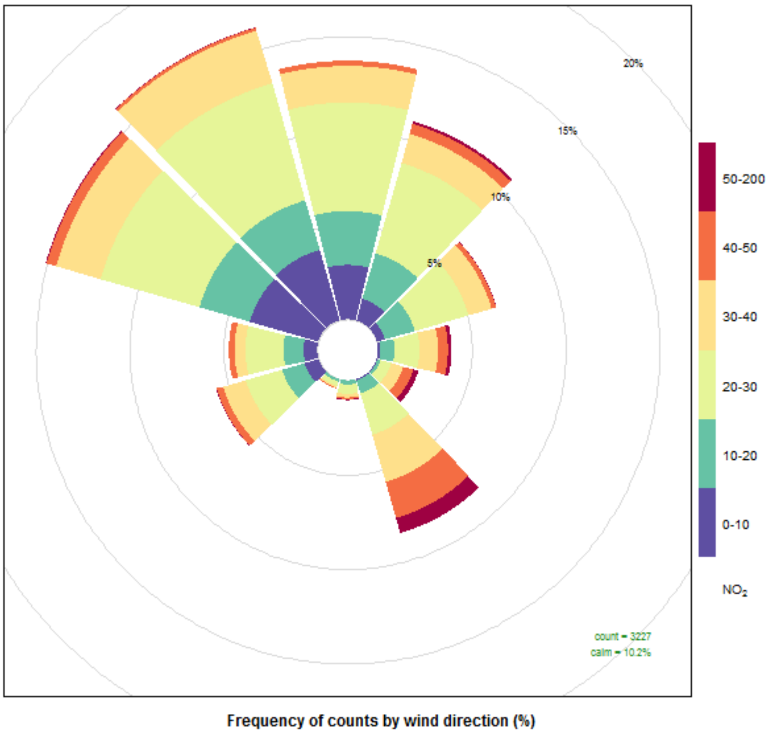

Fig 36. NO_2 Pollution rose in Bab Aliwa 2008 (Gharbi,2012)

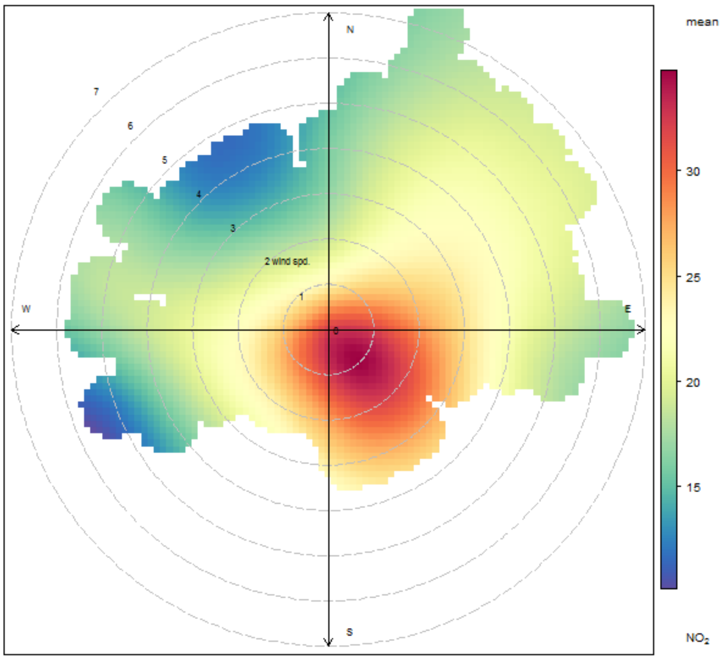

Fig 37. Variation of NO_2 with wind direction in Bab Aliwa 2008 (Gharbi,2012)

The previous plot clearly shows that in Bab Aliwa during year 2008, the dominant wind direction is North East and the highest NO_2 concentrations correspond to the wind from the South East with a speed between 0 m/s and 3 m/s.

- **Sulfur dioxide**

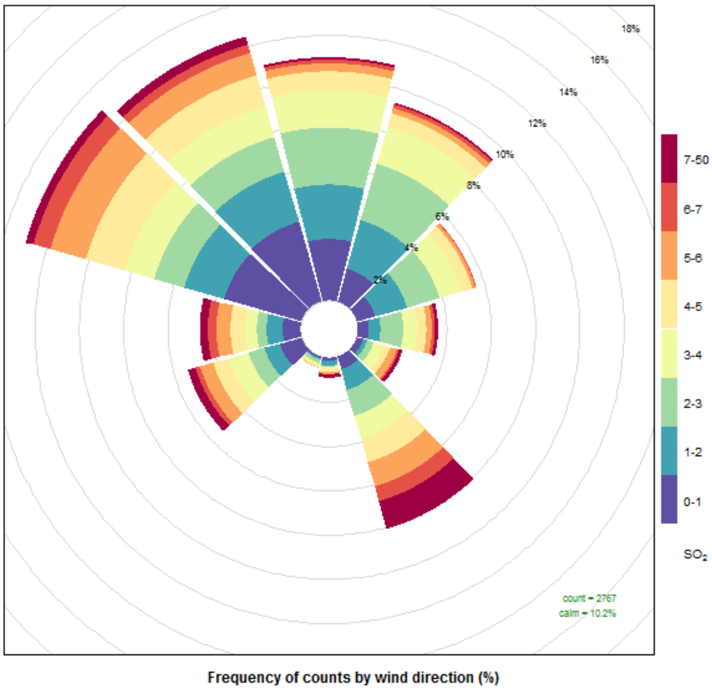

Fig 38. SO_2 Pollution rose in Bab Aliwa 2008 (Gharbi,2012)

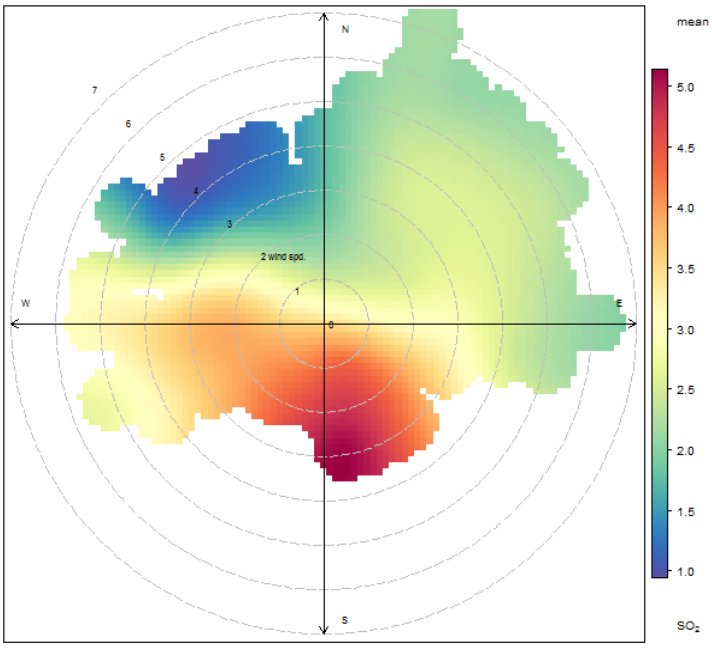

Fig 39. Variation of SO_2 with wind direction in Bab Aliwa 2008 (Gharbi,2012)

This previous plot clearly shows highest SO_2 concentrations when the wind is from the South East, directions of dominant wind with a speed higher than 3 m/s.

- **Suspended particles (PS)**

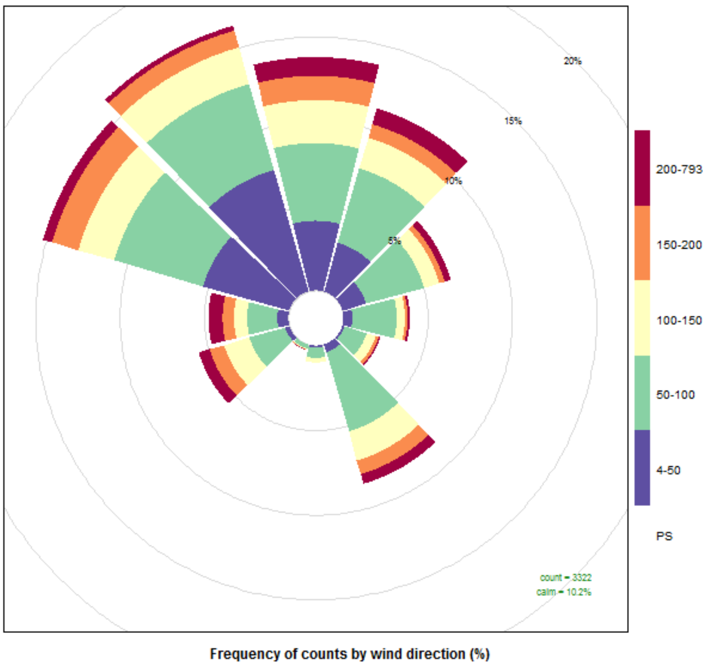

Fig 40. PS Pollution rose in Bab Aliwa 2008 (Gharbi,2012)

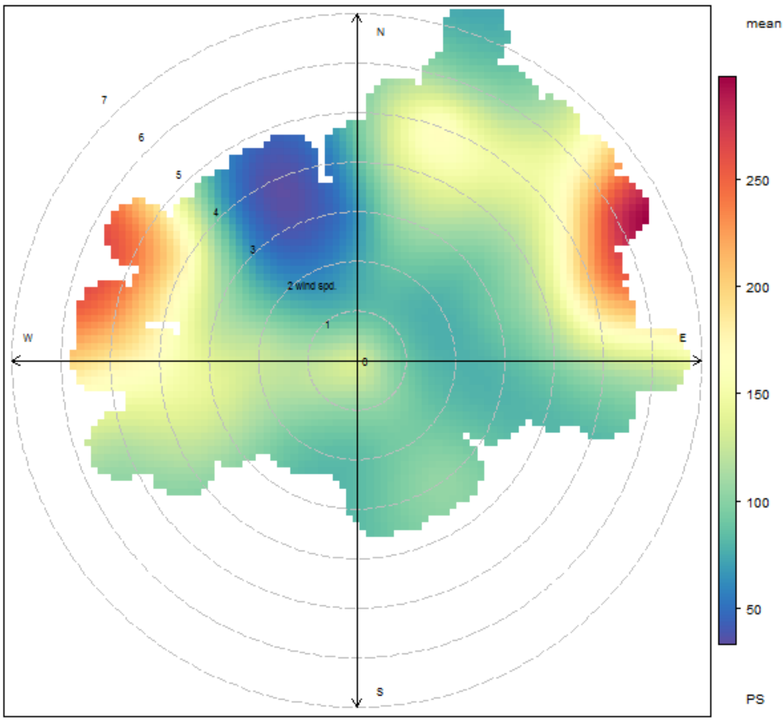

Fig 41. Variation of PS with wind direction in Bab Aliwa 2008 (Gharbi,2012)

This previous plot clearly shows highest PS concentrations when the wind is from the North East and from the North West with a speed higher than 6 m/s for the wind from the North East and higher than 5 m/s for the wind from North West.

V.2 Temperature

The temperature gradient in the atmosphere depending on the altitude is critical to the dispersive power of the atmosphere. In the lower atmosphere, in "normal" conditions the air temperature decreases with altitude. Polluting emissions then tend to disperse more as they rise, the more they find themselves in a cold environment and the difference in temperature favors their elevation. This is the principle of the balloon. However due to some atmospheric factors, it happens that the air temperature increases with altitude. These conditions of temperature inversion are unfavorable to the dispersion of pollutants because when emissions meet a warmer environment, higher mass of air is blocked. This inversion acts as a cover which traps pollution (a) (Fig.42)

In these unfavorable meteorological circumstances, the urban heat island, isolated from the base of a temperature inversion (b) leads to the establishment of a pollution dome (Fig.42).

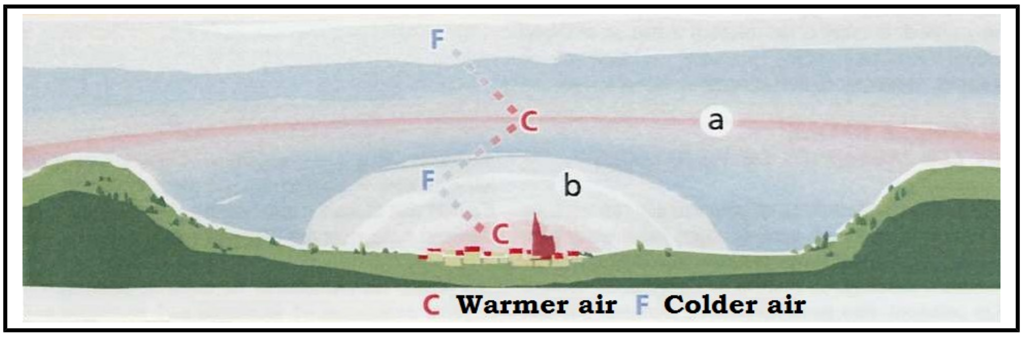

Fig 42. Influence of temperature on the dispersion (El Melki,2007)

The temperature acts on the chemistry of pollutants: cold reduces the volatility of some gas while the summer heat causes the photochemical formation of some pollutants (mainly Ozone O_3).

Nitrogen oxides concentrations in the site of Bab Saadoun at 2004 show a seasonal classic evolution: the highest levels are observed during the winter season (October-February) against by the summer season (March-September) is characterized by the presence of low concentrations.

This seasonal concentrations of nitrogen oxides, is the result of several factors, including the intensity of emission sources is higher in winter than in summer: high traffic and decrease in summer due to summer holidays and the Temperature which is higher in summer than in winter.

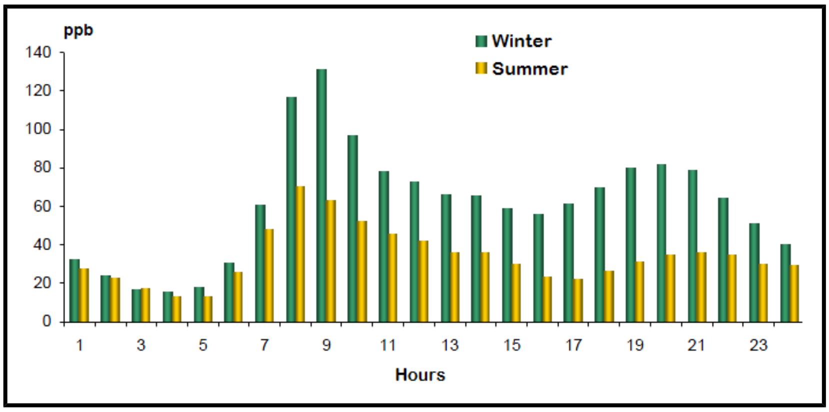

Fig 43. Evolution of NOx during winter and summer in Bab Saadoun 2004 (Gharbi,2012)

V.3 Solar radiation

Ozone and many oxygenated derivatives formed from natural or anthropogenic precursors such as hydrocarbons, nitrogen oxides and carbon monoxide. This pollution, called photochemical formed in summer during strong sunlight.

V.4 Humidity

This is a key factor for the formation of secondary pollutants from primary pollutants, exp:

- Sulfuric acid (H_2SO_4) is formed from sulfur dioxide (SO_2);
- Nitric acid (HNO_3) is formed from nitrogen oxides (NOx).

The curve below shows the anti-correlation between the concentrations of suspended particles and the relative humidity at the station Manouba and behavior and typical for all stations. Indeed, the particles settle under the influence of moisture which can record relative concentrations during the night.

Fig 44. Correlation between relative humidity and particles (dust) in Manouba August 2010 (Gharbi,2012)

PS concentrations tend to be lower during the winter months. During rain, concentrations are relatively low, and on windy days, PS levels can be high.

Conclusions and outlooks

The results presented in this report are the result of statistics carried out by the National Network for Monitoring Air Quality (RNSQA) throughout the study period in collaboration with other institutions who gave contributions and support.

My extensive statistical study summarizes the measured data in different stations and was conducted on the basis of the statistical model CART.

Following this work, we can conclude that the results obtained show a marked variability in levels of air pollution under different influencing factors such as the nature of the environment where the study site and meteorological parameters (humidity, temperature, wind speed and direction).

In urban areas, the highest air pollution levels are measured near roads for urban stations. The contribution of transport is paramount given the daily profiles of major involved pollutants that present regularly peaks at times of increased traffic. We can therefore conclude that traffic causes pollution levels more or less important depending on the number of roads and traffic flow.

The planning and topography also play an important role in the level of atmospheric emissions and strongly influence the quality of the air in Bab Saadoun, especially dust.

Finally, photochemical reactivity generally have a prominent impact on the state of air quality and are more particularly, to the origin of the formation of secondary pollutants.

Given the foregoing, development projects and research programs in the field of air quality, is the best way to understand our atmospheric environment.

To better control pollution several innovative approaches responding to new challenges need to be strengthened as follows:

- Continued efforts to implement new monitoring stations of the air quality throughout Tunisia.
- Diversification of monitoring and enhancing the activity of forecasting (mapping, statistical modeling and deterministic).
- Information and awareness
- The development of studies and research in collaboration with various agencies of the ministry of higher education and Scientific Research
- The strengthening of international cooperation

- The introduction of quality management ISO 9001 version 2008 in the direction in monitoring air quality.
- Consolidation of the regulatory and normative framework by the publication of the first text law enforcement on air quality: "the decree setting the limits to the source of air pollutants from stationary sources".

So, it will be question in the coming years of:

- Better implement the law on air quality and the implementing legislation and strengthening the means of monitoring the quality of ambient air or from source.
- Develop better technology for better monitoring of air quality,
- Develop ways to forecast air quality and by creating a platform for modeling emissions,
- Initiate communication activities whether by means of written communication and report or newsletter campaigns for young and old,
- Develop studies and research.

It is therefore necessary to express an integrated approach linking different parts of the air pollution (emissions, air quality, and atmospheric deposition) and suggest a confrontation with other issues including climate change, the energy, transport and planning.

It has also become necessary to rely more on the mobilization of all public actors private and individuals. Such mobilization would not happen without an awareness of the shared responsibility of releases vis-à-vis health and environmental impacts.

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