1 Introduction

Air pollution is a serious problem in many heavily populated and industrialized areas in the world (Simpson and Layton, 1983, Kambezidis et al., 1996) and the issue of urban air quality is receiving more attention as an increasing share of the world's population is now living in urban centres and is demanding a cleaner urban environment.

In many developing countries of Asia, Latin America and Africa, air pollutants emission has been increasing over the last two decades. This has been primarily due to rapid economic growth in many of these countries, resulting in increasing urbanization, transportation, industrialization and energy generation (UNEP, 1997). The industrial activities of man and the uncontrolled development of large cities have resulted in the contamination of air, soil and water. Urban air pollution not only has immediate localized impacts on human health and well-being but also affects the regional environment and plants. The environmental impacts are particularly severe in cities with a very large number of inhabitants, especially in Asia, where some countries have a combination of intense industrial activity, large population density and an extremely high number of motor vehicles (Gary and Wha-Jin, 2002).

The main cause of urban air pollution is the burning of fossil fuels (coal, oil and natural gas) in domestic heating, power generation, industrial processes and in motor vehicles. In addition, the burning of biomass such as firewood, agricultural and animal waste in some cities contributes towards increasing the level of pollution. In developing regions, especially the number of motor vehicles is increasing exponentially. Asia has experienced, with 40% between 1980 and 1995, the greatest increase amongst developing countries. Therefore, motor vehicles are, in many urban areas of Asia, especially near the traffic centres, the main sources of air pollution (Mudd and Kozlowski, 1975). According to the World Resources Institute (1994) emissions from motor vehicles represent 57% to 75% of total urban pollutants emissions in the large cities of Iran (Tehran, Mashhad, etc) and of India (Delhi, Bombay, etc).

In Iran, as in most other regions of Asia, air pollution has been aggravated by a number of developments such as the growth in the size of cities, rapid economic development, industrialization and increasing traffic and levels of energy consumption. The movement of people into urban areas together with the increase in consumption patterns and unplanned urban and industrial development has led to the serious problem of air pollution. Besides transport and industrial sectors, construction activities and roadside airborne dust due to vehicular movement also contribute to the overall pollution load in most of the cities in Iran.

During the last few years, especially the number of vehicles in Iran, mostly operated by leaded fuel, has increased rapidly leading to increasingly high levels of some heavy metals and other pollutants in the soil and plants near highways in both rural and urban areas.

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmospheric environment. It can operate as an environmentally friendly alternative to traditional technologies by reducing air pollution; provide improved air quality, primarily through leaf uptake of such pollutants as ozone, sulphur dioxide, carbon monoxide, nitrogen dioxide and particulate matter. Other benefits provided by urban vegetation include improved local climates (blocking winds, controlling storm water run-off, shading surfaces, modifying the storage and exchanges of energy among urban surfaces and consequently energy use in buildings), noise abatement, improved physical and mental health and well-being, aesthetic environments, wildlife habitat enhancement and increased property values (Sacamano et al., 1993).

Plants growing in urban areas have to face continuously various environmental constraints, of which an important and increasingly concerning one is the pollution with heavy metals (Singh et al., 1995 and ETCS, 1998). Although there have been a considerable number of studies on the concentrations of heavy metals in plants, the vast majority have been carried out in developed countries with histories of industrialization and extensive use of leaded gasoline since 1935 (Ward et al. 1975 and 1974; Ndiokwere, 1984 and Jaradat and Momani, 1999). Very few studies have

been carried out in developing countries such as Iran, and data on pollutant metal concentrations and distribution in such areas are extremely scarce.

The aim of this study is to assess the level of contamination of plants and air by some heavy metals and their effect on anatomical and morphological characteristics of leaf. The investigations were carried out on *Platanus orientalis* in Mashhad City. Two sites were chosen for the investigation, one in the city centre with heavy traffic density (heavily polluted site) and another one about 20 km distant from the city centre with a very low traffic density (less polluted site).

Platanus orientalis was chosen because it is a tree adapted to different ecological conditions and a widely distributed dominant tree in parks as well as along roads and streets of Iran. In the last years, *Platanus orientalis* has been increasingly affected by air pollutants, especially in areas with a high traffic density.
Mashhad City was chosen as investigation area because many activities like industrialization processes, domestic heating, the burning of oil fuel, and the use of fuel in motor vehicles take place in Mashhad areas. It is the second largest city in Iran, and the population has experienced an important demographic rise during the last years.
In 2006, Mashhad has a population of nearly 3 million and is visited by more than 20 million pilgrims every year (http://en.wikipedia.org/wiki/Mashhad). This has led to an exponential increase of small and large vehicles, and motorcycles (700.000 to 1000.000) emitting a high level of air pollution.

The investigations were focused on measuring Pb, Cu, Cr, Co and Zn in the air and their effect on chemical, anatomical and morphological characteristics of *Platanus* leaf. Tree leaves represent the seat of active growth processes. They are usually the most satisfactory parts of plants on which to make analyses. Other parts of the plants often function as storage organs and draw upon the various elements absorbed in a selective way (Wallace, 1943).

As mentioned, there have been no studies about the extent of contamination of the roadside ecosystem with priority on heavy metal pollutants in Iran. Therefore, this study should be considered as pioneer work.

2- Material and Methods

2.1 Study area

2.1.1 Location

Iran is located in Middle East, bordering the Gulf of Oman and the Persian Gulf in the South and the Caspian Sea in the North. Iran is neighbor with Iraq in the West and Afghanistan and Pakistan in the East.

The study area was the City of Mashhad, a Holy City located at 36.20º latitude north and 59.35º longitude east, in the valley of the Kashef in the North-East of Iran, at a distance of about 850 kilometers from Tehran. It is situated at about 985m above sea level. The basin of Mashhad is surrounded by the two mountain ranges of Binalood and Hezar-Masjed (Fig. 1).

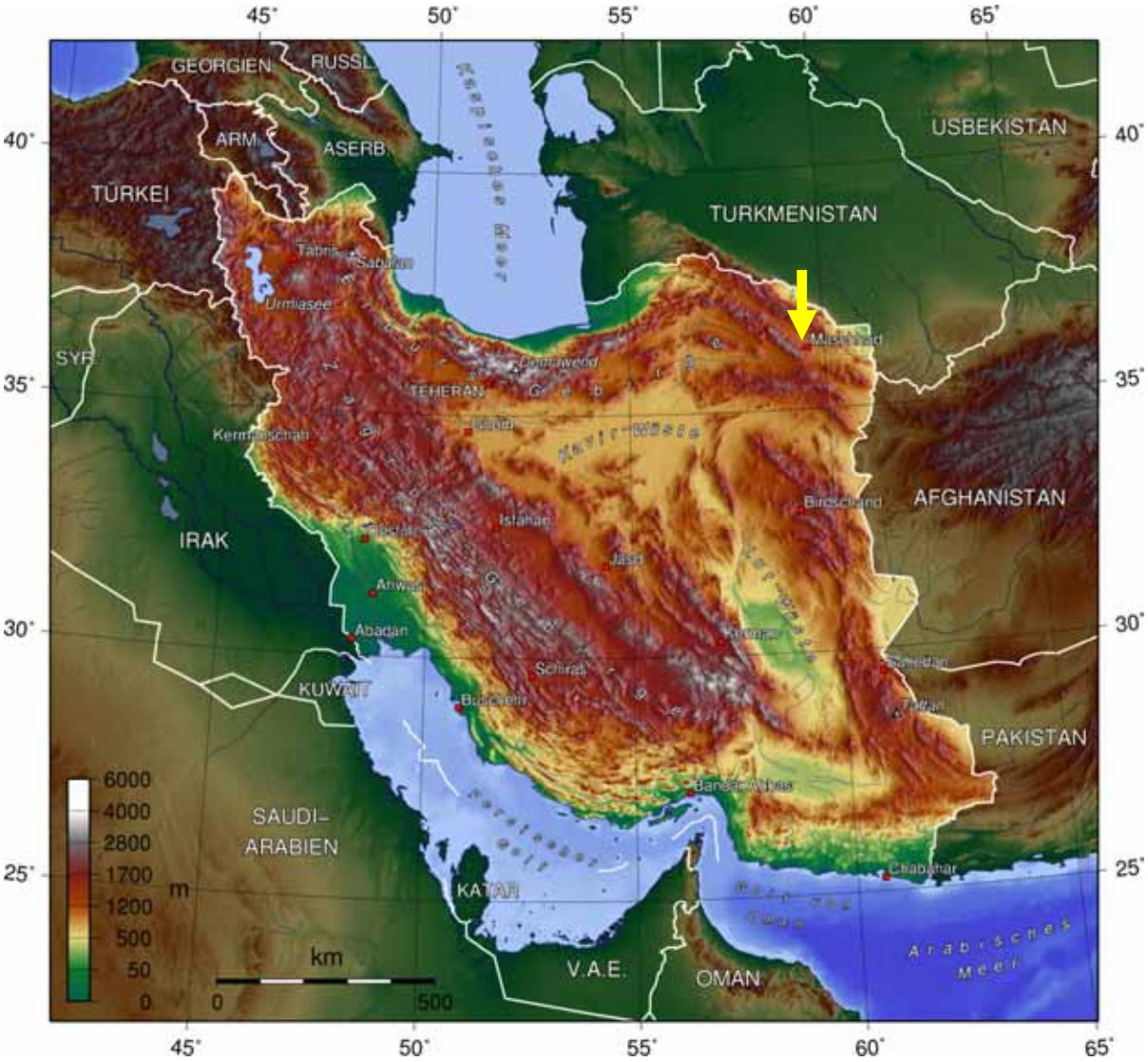

Figure 1: Topographical map of Iran (http://upload.wikimedia.org/wikipedia/de/9/91/Iran_topo.jpg)

2.1.2 Climate

Mashhad has a semi-arid climate which is characterized by an extreme hot summer, very cold winter and a very low precipitation during the year. The annual average temperature in Mashhad is 13.5°C and the average annual rainfall is 248 mm, most of which occurs from February to April.
The dominant wind direction is south, south-west and south-east with generally moderate wind velocities in different seasons, which tend to encourage particle deposition close to or far from the emission source.

Mashhad is the capital of the Razavi Khorasan province and its centre of commerce and industry and has moderate industry, a population of almost 3 million (http://de.wikipedia.org/wiki/Mashhad and oral statement of the Urban Planning and Architecture Research Centre of Mashhad) and heavy traffic.
The main industries are ceramic, brick, glass, food industry, leather, carpet and textile industries which are distributed in different areas and are sometimes surrounded by residential settlements. These scattered industries use all types of fossil fuel and emit together with 700.000 to 1000.000 small and big vehicles and motorcycles several air pollutants into the atmosphere of the region.
For the assessment of the air pollutants and their effect on *Platanus orientalis*, two sites, one heavily polluted and another less polluted, were chosen in Mashhad (Fig. 2). The heavily polluted site is located at the city centre roadsides exposed to the exhaust of heavy traffic. The less polluted site (Torghabeh) is at a distance of about 20 km from the city centre along roadsides with a very low traffic density.

Figure 2: Location of investigated site (Source: www.googleearth.com)

Figure 3: A view of a street with *Platanus orientalis* in Mashhad City

2.2 Chemical analysis

2.2.1 Chemical analysis of air

For the chemical analysis of air, twenty-four hours sampling was done, using a high volume sampler (Dehm & Zinkeisen Firm) which sucks air pollutant and aerosol through Teflon filters (Fluopore membrane filter, Millipore firma). Teflon filters of <0.2 μm particle size and 47 mm diameter were used.

For the installation of the high volume sampler, buildings adjacent to the sites investigated were chosen. The high volume sampler was located at 2m above the roof of the buildings which have a height of approximately 10m. Because of technical and electricity problems, air samples could only be collected at four locations at each site.

The collection of the air samples was carried out May, July and September 2005, once a week on a 24 hours sampling basis at each site. The filters were removed from the sampler and were kept in polyethylene bags to minimize sample loss until the time of analysis.

The pollutant on filters was extracted with 65 % HNO_3 digestion method (Koenig and Fortmann, 1999). The concentrations of Pb, Cr, Co, Cu, Ni and Cd in the solution were measured by Graphite Furnace Atomic Absorption Spectrometry (Backstrom and Danielsson, 1990) and the other concentrations of element by Inductively Coupled Plasma Atomic Emission Spectrophotometry (Singh et al., 1995). The results were calculated in ng m^{-3}. A total of 24 air samples were collected and analysed.