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Air pollution in Northern Africa

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Summary
Suspended dust (measured as TSP, PM_{10} or $PM_{2,5}$) is normally the major air pollution problem in Northern Africa. This has also been clearly demonstrated from data collected in Egypt. Annual average concentrations of PM_{10} often exceeded 100 µg/m^3 in urban and residential areas and can reach up to 500 µg/m^3 near industrial areas. Typical for most of the North African areas are relatively high natural background concentration of PM_{10} caused by sand storms and high dust level episodes. In Egypt the "natural background levels" have been evaluated to represent concentrations close to or around the Air Quality Limit value of 70 µg/m^3 as a daily average.

High concentrations of surface ozone have also been observed as a result of regionally produced secondary pollutants in many areas of northern Africa. The 8-hour average ozone concentrations are most often exceeding the international guideline values of 100 µg/m^3 (WHO 2005).

Traffic, power production and industries are the main sources of surface based air pollution. The concentration levels of SO_2 and NO_2 have been observed to exceed the Air Quality Limit values in industrial areas and during some occasions in the big cities. Both the long term (annual averages) and the short-term (1-hour average) Air Quality Limit levels have been exceeded. Eight-hour average CO concentrations in streets and along roads are frequently exceeding the Air Quality Limit value.

1 Air pollution in Egypt

The Egyptian Environmental Affairs Agency (EEAA) has been supported by Danida to establish an Environmental Information and Monitoring Programme (EIMP) for Egypt. The national air pollution monitoring programme developed by EIMP consisted in 2004 of a total of 42 measurement sites covering most of Egypt. This programme consisted of a total of 14 sites located in the greater Cairo area, 8 sites in Alexandria, 10 sites in the Delta and Canal area, 9 sites in upper Egypt and 1 site in Sinai. As of 2009 this programme has been expended, and it is presently being reorganized with new operators and a total of about 60 measurement stations for the whole country, out of which 23 stations are located in the greater Cairo area.

1.1 Suspended particles

Suspended particles are the major air pollution problem in Egypt. Annual average concentrations of PM_{10} range between 100 and 200 µg/m^3 in urban and residential areas and between 200 and 500 µg/m^3 near industrial areas. The natural background concentration of PM_{10} in Egypt has been evaluated to represent levels close to or around the Air Quality Limit value of 70 µg/m^3 as a daily average.

Concentrations of suspended dust measured as PM_{10} are exceeding national and international air quality limit values at all sites in Egypt. Monthly average concentrations are commonly recorded at between 200 and 300 μg/m^3. Typical annual average concentrations are presented for 25 sites in Figure 1.

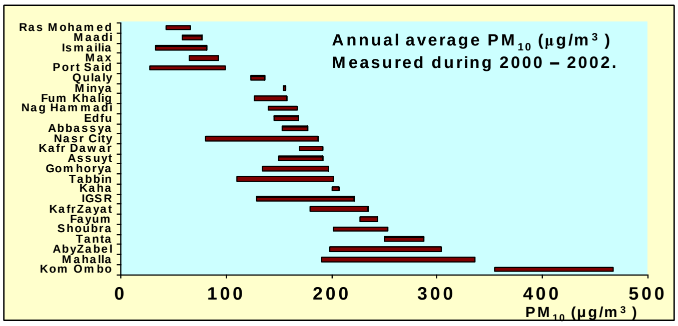

Figure 1: The range of annual average PM_{10} concentrations measured at 25 sites in Egypt (2000 - 2002)

In the greater Cairo area the air quality limit value (AQL) of 70 μg/m^3 as a 24-hour average concentration was exceeded between 45 and 98 % of the time in 2002. Similar periods of exceeding have been observed both before and after 2002. An analyses of typical "background" PM10 concentrations in Cairo indicated that these background levels were about as high as the air quality limit values given by the Law (EEAA, 1994).

1.2 SO_2 and NO_2 concentrations

The concentration levels of SO_2 and NO_2 have also been observed to exceed the Air Quality Limit values in industrial areas and during some occasions in the big cities.

Long-term average concentrations estimated from passive sampling of SO_2 are presented in Figure 2.

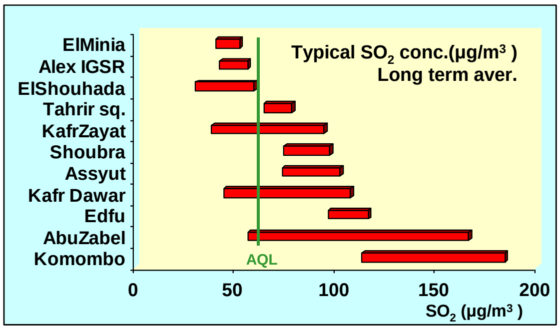

Figure 2: Typical ranges of long-term average (annual) concentrations of SO_2 measured by passive samplers at 11 selected sites in Egypt.

Again we see that sites impacted by industrial emissions are exposed to the highest concentrations of SO_2. Even at Tahrir Square, in the city centre of Cairo, the SO_2 level was slightly higher than the limit values.

Annual average concentrations of NO_2 ranged in 2002 between 25 and 83 μg/m^3. In the streets of Cairo the average concentrations were between 75 and 83 μg/m^3. Similar concentrations are also measured in 2009.

The one-hour average limit value of 400 µg/m^3 has not been exceeded at any of the monitoring stations. However, the 24-hour average limit value of 150 µg/m^3 is occasionally exceeded in narrow streets of Cairo on days with high traffic and poor dispersion conditions.

1.3 Ozone concentrations

The regional background measurements undertaken at Ras Mohamed at the southern tip of Sinai indicated that the background ozone level is on the average higher than the levels measured in Cairo and Alexandria.

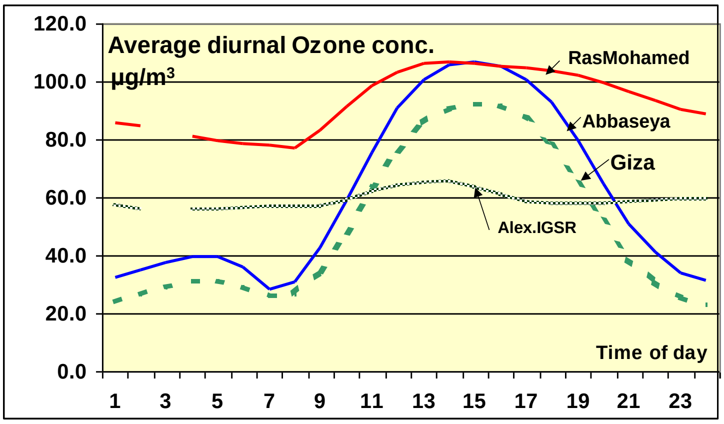

Figure 3: Annual average diurnal variation of ozone measured at 4 sites in Egypt 2000-2002.

Figure 3 indicates that daytime ozone concentrations often exceeded 100 µg/m^3, which is the WHO-2005 guideline value. In Alexandria we see that the ozone levels are influenced by NOx emissions from traffic in the city. The "fresh" NOx emissions are "using" ozonein order to form NO_2. The ozone concentrations are therefore relatively low at the sites located inside the urban boundary layer.

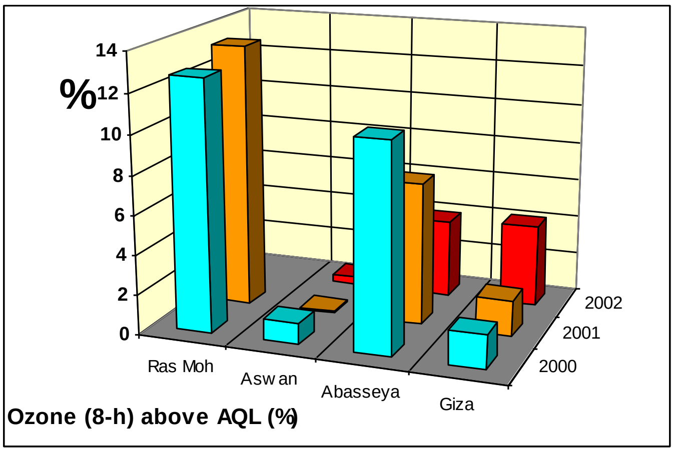

Figure 4: The frequency (%) of 8-hour average ozone concentrations exceeding the AQL of 120 µg/m^3 .

The 8-hour average limit value of120 µg/m^3 (EEAA, 1994) was exceeded more frequently than the one-hour average limit values, as the relatively high ozone concentrations during the summer season seem to last for several hours. Exceedances of the limit values are found most frequently during the summer season.

1.4 Air pollution episodes

Periods of high air pollution levels have been observed frequently during the last few years in Cairo due to high emissions of air pollutants from different sources combined with specific meteorological conditions. These so called “episodes” occur most frequently in October every year. They may be caused by a combination of low-level sources inside the city of Cairo, burning of agricultural waste in the Delta and unfavorable meteorological conditions.

Also in October 2009 we had several days with concentrations of PM_{10} and gases much higher than typical average concentrations as well as limit values. On 3 to 6 October 2009 very high concentrations of PM_{10} were recorded at sites in the Delta area, at Abbaseya and Nasr City in Cairo and later also in Helwan south of Cairo. The winds were from the north at 2 m/s at night and in the morning hours. A cloud of particles passed Cairo during night time, concentrations decreased at day time and raised again after sunset to reach Helwan, south of Cairo, two hours later at 20:00 hrs. The peak concentrations in the early evening reached 400 to 600 µg/m^3.

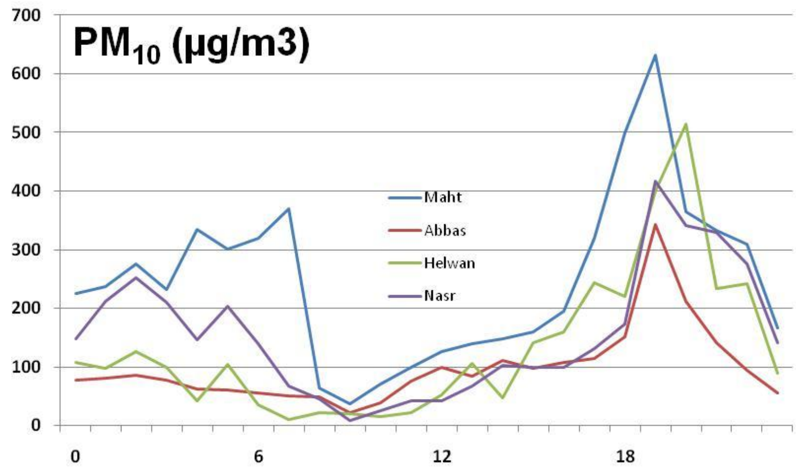

Figure 5: Concentrations of PM10 at four stations in greater Cairo area on 3 October 2009.

During these episodes the plumes of dust were observed moving into Cairo in the morning hours from north. Satellite pictures have also revealed that during these days there were fires observed over the eastern part of the Delta. Wind trajectory analyses also indicated transport of air from the northerly directions towards Cairo.

To identify the importance of the burning of this agricultural waste in the Delta relative to the importance of local sources inside Cairo, we have to analyze a selection of filters collected during the days of interest. Gertler et al. (2004) performed a source attribution study to determine contributions from various sources in Cairo. Samples of PM_{10}, $PM_{2,5}$, PAH, and VOC were collected on a 24-hour basis to identify the importance of the burning of agricultural waste in the Delta. At a site in northern Cairo, close to the Delta, PM_{10} contribution from burning was estimated at 40 %, for $PM_{2,5}$ the contribution was 30 % . Inside the city centre the open-air burning contribution was estimated at 42% both for $PM_{2,5}$ and PM_{10}.

2 Dust storms

Very high concentrations of suspended particles are observed in northern Africa and the Middle East during dust storm. Hourly and daily average concentrations of PM_{10} during sand storms or dust cloud conditions may be reported five to ten times the typical average concentrations. Data from a number of such dust clouds are available.

Severe sandstorms have been experienced in Cairo and other parts of Egypt several times, blanketing the area under a layer of orange dust. One sandstorm in April 2007 reduced the visibility to less than 100 meters in places forcing the closure of Cairo's International Airport for several hours, with five Egyptian ports in the Gulf of Suez also shutting down.

Figure 6: A sand storm experienced in Cairo in April 2007.

The sandstorm affected traffic with a number of accidents reported, while residents, especially the elderly, suffered from breathing problems. The dust was said to have been so thick that it was impossible to see across the River Nile. Two people were killed by a fire which was fanned by the strong winds. Egypt is certainly not a stranger to sandstorms, where they are known as Khamaseen or the 50-day wind. A Khamaseen is said to be a hot and oppressive south to southeast wind which becomes dusty and laden with sand. As it descends on cities it deposits a layer of sand on buildings and cars.

Dust storms of this kind occur over northern Africa and the Middle East from Morocco to the Gulf States. A typical example was recorded in December 2005, when the storm whirled from the southwest toward the northeast in Algeria, south of Tunisia, and into Libya.

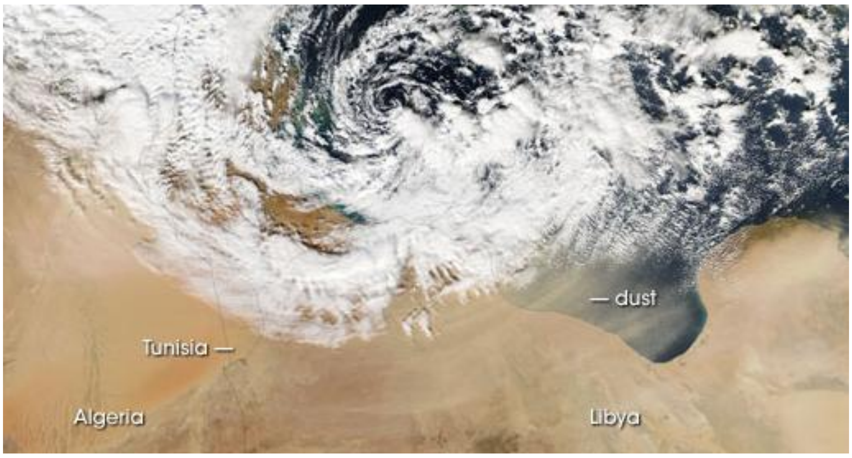

Figure 7: A dust storm swept off the north coast of Africa on 14 December 2005. The Moderate Resolution Imaging Spectro radiometer (MODIS) captured this image the same day from the Aqua satellite.

The dust clouds finally dissipate over the Mediterranean north of Libya. Clouds, perhaps part of same weather system that kicked up the dust, obscure the view of the north coasts of Algeria and Tunisia, but most or all of the dust appears to be passing over Libya. As all three of these countries are part of the Sahara Desert, one of the world's most prolific dust producers, dust storms are common in these countries. Dust storms are reported almost every year; the last major one in January 2009.

To illustrate the ratio between average PM concentrations and concentrations during dust storms we have selected a dust storm appearing in Abu Dhabi in March 2009.

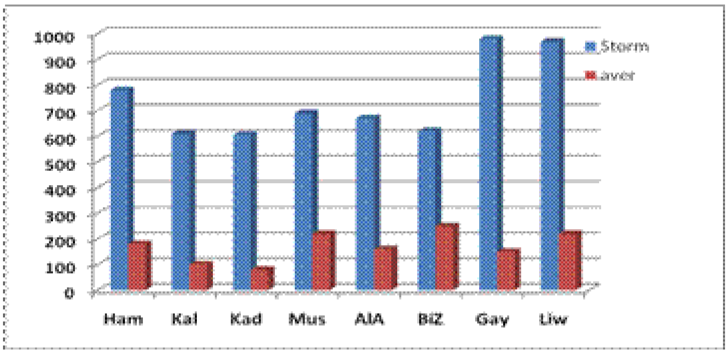

Figure 8: PM_{10} concentrations measured during a sand storm in Abu Dhabi recorded on 3 March 2009. Short term concentrations measured during the storm are shown together with typical average PM_{10} concentrations at 8 sites in Abu Dhabi.

The typical situation from March 2009, presented in Figure 8, illustrates the impact from sand storms and dust clouds (Sivertsen & ElAraby, 2009). PM_{10} concentrations measured on 3 March 2009 have been compared to typical long term average PM_{10} concentrations measured at 8 sites in Abu Dhabi.

During this case we see that the short term maximum concentrations were 4 to 8 times the average PM_{10} concentrations measured for the same month. The highest ratios appeared at the regional background stations, while the ratios were less at sites that normally are more polluted such as industrial sites and in the downtown traffic impacted areas.

3 Tunisia

In Tunisia, energy generation and the transport sector are among the major contributors to air pollution, at 31 per cent and 30 percent respectively. Local sources contributed to concentrations of NO, NO_2, CO, SO_2 . High PM_{10} concentrations are generally the main problem in Tunisia. The main sources were vehicles, industries and "natural sources". The average diurnal variation of PM_{10} measured at 9 sites in Tunisia during 2006 indicates in Figure 8 that the PM_{10} concentrations normally ranged between 50 and 100 µg/m3. Up to 200 µg/m^3 were observed as averages in urban areas during evening inversion conditions.

High concentrations PM_{10} were in some cases due to impact from regional sources. This is normally also the case for high ozone concentrations.

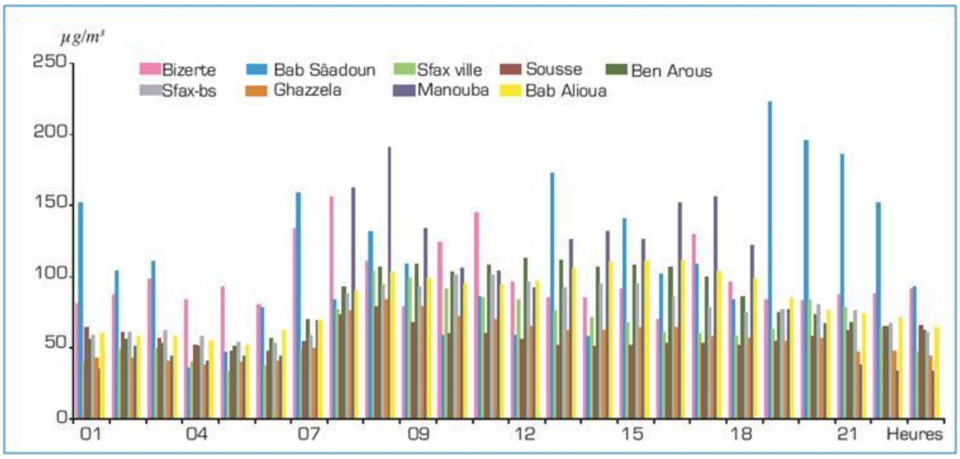

Figure 9: Average diurnal variation of hourly PM10 concentrations measured at 9 sites in Tunisia during 2006.

High SO_2 concentrations were only measured downwind from specific industries. Measurements from one site in Sfax showed that national and international standards could be violated during specific meteorological conditions (Azri et.al 2007).

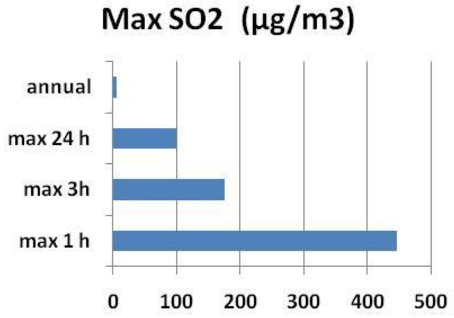

Figure 10: Maximum SO_2 concentrations measured in the Sfax area 2006.

NO_2 concentrations seldom exceeded air quality limit values. Typical hourly maximum concentrations at 4 selected sites ranged between 80 and 100 µg/m^3. The main source for these concentrations is vehicle emissions.

CO_2 and other GHG emissions originating mainly from the transport sector, rose from 3.4 million tonnes to 5.8 million tonnes between 1994 and 2002, with an annual increase rate of 9 per cent. The total emissions generated by the energy sector accounted for about 29 percent in the year 2002, rising from 23 percent in 1994.

4 Morocco

Air pollution in Morocco is mainly due to road traffic and industry, particularly along the Mohammedia-Safi road axis. AQ measurements are undertaken in several urban areas. Permanent networks have been established in Casablanca and in Rabat. Monitoring of vehicle emissions is also being undertaken in several cities, and emission limits have been established for power plants.

One of the main air pollution problems also in Morocco is PM_{10}. Daily average concentrations exceeded the national limit value of 200 µg/m3 at 6 of 9 monitoring stations in Rabat and Casablanca (Figure 11)

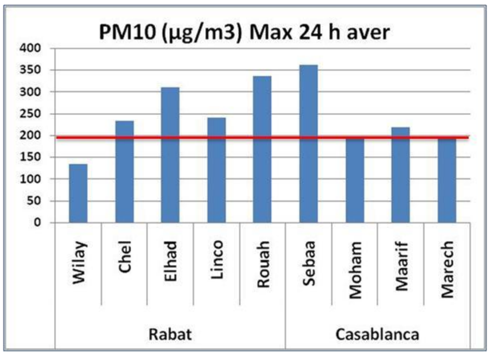

Figure 11: Maximum daily average concentrations of PM10 at measurement sites in Rabat and Casablanca. (RNSQA, 2008))

Also SO_2 concentrations were observed exceeding air quality standards (Figure 12).

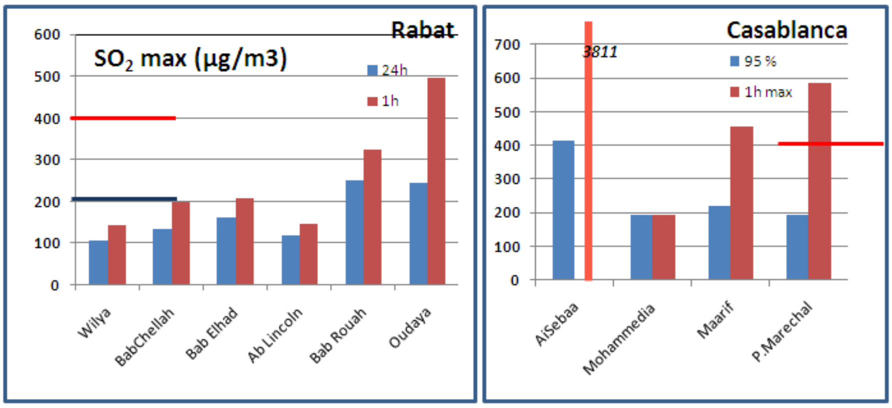

Figure 12: Maximum SO_2 concentrations measured in Rabat and Casablanca (RNSQA, 2006)

The effect of the deterioration of air quality on the economy, in terms of the decrease of productivity due, in part, to respiratory diseases, is estimated at 1.9 percent of the Gross Domestic Product (GDP) (WRI, 2005).

5 Libya

In Libya, the main sources of air pollution are related to the use of petroleum derivatives as fuel in many industrial, artisan and transport fields. Oil refineries are the main sources of atmospheric pollution due to the harmful gas emissions, mainly hydrocarbons, carbons, nitrogen oxides and sulphur from burning fuel in oilfields and refineries.

Most of the plants were not subjected to environmental evaluation prior to their establishment, and they have adverse effects on the surrounding residential and maritime areas. The plants do not have the necessary pollution control, monitoring and measurement systems, nor the necessary equipment and devices for limiting or decreasing the volume and concentration of the pollutants.

Libya has the highest per capita emission of CO_2 in North Africa (about 9 tons per capita per year). The total CO2 emissions per year (ca 50 mill tons/yr) is about the same as Morocco. The total SO_2 emissions in Libya are about the same as Algeria, Tunisia and Morocco (between 220 and 300 ktons/yr).

6 SO_2 , NOx and CO_2 emissions in North Africa

All countries in northern Africa experienced significant growth in CO_2 emissions during the last few years. This increase is often correlated with economic growth. For example, there was a 14.3 percent increase in per capita CO_2 emissions between 1990 and 2001 in Libya.

Emission data for North Africa are based on the Emission Database for Global Atmospheric Research (EDGAR) 2000. Updates of emissions data largely depend on the availability of the international statistics utilized in emissions estimations. These data have been produced as a top-down emission inventory by the Netherlands National Institute of Public Health and the Environment (RIVM) and the Netherlands Organization for Applied Scientific Research (TNO) based on greenhouse gas emission inventories.

African emissions of SO_2 are about at the same level for Algeria, Libya, Tunisia and Morocco, (210 to 300 ktons/yr), while the SO_2 emissions from Egypt are about 3 times higher. The emissions of SO_2 are mainly generated by burning of fossil fuel and from industrial processes.

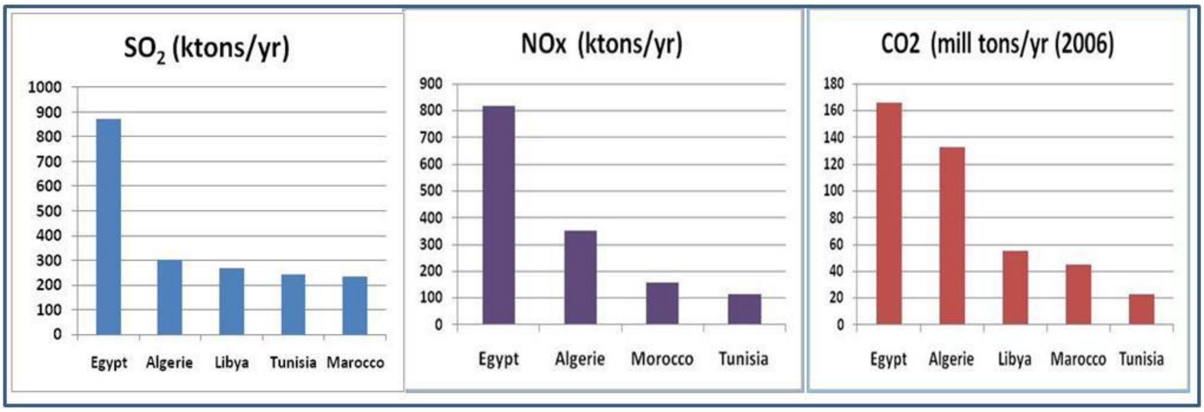

Figure 13: Annual emissions of SO_2 , NOx and CO_2 in 5 countries of North Africa (UNEP, 2006)

Nitrogen oxides, or NO_x, is the generic term for a group of highly reactive, acidifying gases, all of which contain nitrogen and oxygen in varying amounts. Nitrogen oxides are a precursor to ground-level ozone, which can trigger serious respiratory problems. NO_x also contribute to acid rain and global warming. They form when fuel is burned at high temperatures, as in a combustion process. The primary sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.

Total annual CO_2 emissions in the 5 countries in North Africa varied considerably from one country to another, as seen in Figure 13. The annual emission of CO_2 in Tunisia was 20 mill tons, in Egypt about 165 mill tons.
To ensure a consistent approach across countries, RIVM obtains activity data from a variety of international statistical data sources (IEA, UN, FAO, OLADE, etc.) and selects emission factors from international publications (Intergovernmental Panel on Climate Change (IPCC) Guidelines, US-EPA reports, etc.).

7 Some conclusions

One of the main air pollution problems in North Africa is suspended particles. A fair fraction of this problem has been linked to natural dust and frequent occurrence of sand storms. Important sources to the smallest particles are also emissions from traffic, industries and open air waste burning, which in some areas has been a problem. High concentrations of NO_2 are mainly related to vehicle emissions, while SO_2 seem to mainly an industrial problem.

It has been recognized earlier that North Africa and the Arab region is suffering from shortage of institutional capabilities for monitoring, analysis, assessment and control of air quality conditions at many aspects of its development. This is presently being improved. Transportation systems, excessive use of polluting fuels in industry, shortage of awareness of stakeholders and the rapid growth of urbanization constitute major factors responsible for poor air quality.

Dr El Raey (2000) concluded that “There is a need to improve and establish air pollution monitoring and control programmes for mobile and stationary emission sources, and to continue assessment and analysis of ambient air data. It is necessary to use sound urban planning for cities with support systems that are environmentally sound and have low energy consumption."

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