NILU: F 145/2003

NILU: F 145/2003
REFERENCE: Q-303
DATE: OCTOBER 2003

Baseline of Air Pollution from 2000 to 2002

Presented at the 4th International Exhibition for Environmental Technologies "Environment 2003", Cairo, Egypt, 30 September to 2 October 2003

Bjarne Sivertsen[1], Haytham Ahmed[2], Ashraf Saleh[2] and Ahmed Abu El Seoud[2]

1) Norwegian Institute for Air Research (NILU), Kjeller, Norway
2) Egypt Environmental Affairs Agency (EEAA), Cairo, Egypt

Contents

Baseline of Air Pollution from 2000 to 2002

1. Introduction

Industry is one of the main sources of Egyptian economy; therefore the Egyptian government has focused on the modernization, expanding and investing in this sector. This process has been started since the year of 1981 and still running to improve the level of the Egyptian industry. Although this process has achieved part of its goals, it also led to the increase of pollution in the industrial areas. At early stage the Egyptian Environmental affairs agency (EEAA) as part of the Egyptian government has realized the effect of industrial pollution on the environment. Taking this point into consideration the Agency has been supported by Danida to establish an Environmental Information and Monitoring Programme (EIMP) for Egypt. The EIMP components were launched in 1996 with EEAA as the implementing agency for an environmental information and monitoring programme covering institutional support, coastal waters, air pollution, point sources emissions and the development of reference laboratories for improvement of the quality of monitoring data. The national air pollution-monitoring programme developed by EIMP consists of a total of 42 measurement sites covering most of Egypt.

2. The air quality measurement programme

A total of 42 measurement sites have been selected covering most of Egypt. Two monitoring institutions have been selected for undertaking the field operations and collection of data. The Center for Environmental Hazard Mitigation (CEHM) at Cairo University and the Institute of Graduate Studies and Research (IGSR) at Alexandria University are operating, on behalf of EEAA, 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. The monitoring program has been designed and established by EIMP. The monitoring laboratories both at CEHM and at IGSR are submitting quarterly reports as a support for the data collection and. These reports briefly describe data quality, data availability and the air quality. A Reference Laboratory has been set up at the National Institute for Standardization (NIS).

2.1 Selected sites

The EIMP Air Quality Monitoring Programme is providing information to support and facilitate the assessment of air quality in the selected areas. The information provided by the EIMP Programme will:

- Provide a general description of Air Quality, and its development over time (trend)
- Enable comparison of Air Quality from different areas
- Produce estimates of individual source contributions
- Indicate the exposure of air pollution to the population
- Evaluate levels of pollution compared to national and international limit values
- Represent input to future information and assessment of air quality

The number of sites and area types are presented in Table 1.

Table 1: Number of sites in different types of areas

Area type	Cairo	Alex.	Delta and Canal	Upper Egypt	Sinai	Total
Industrial	3	3	3	2		**11**
Urban	1	1	3	4		9
Residential	4	2	2	2		10
Street/road	3					3
Regional/backr.	1	1			1	3
Mixed areas	2	1	2	1		6
Total	14	8	10	9	1	**42**

The design, development, construction and installation of the measurement programme started in 1997 and were completed in July 1999. CEHM is operating 27 Monitoring and Sampling sites in Cairo, Canal area, Upper Egypt and Sinai while 15 sites are being operated by IGSR in Alexandria and Delta.

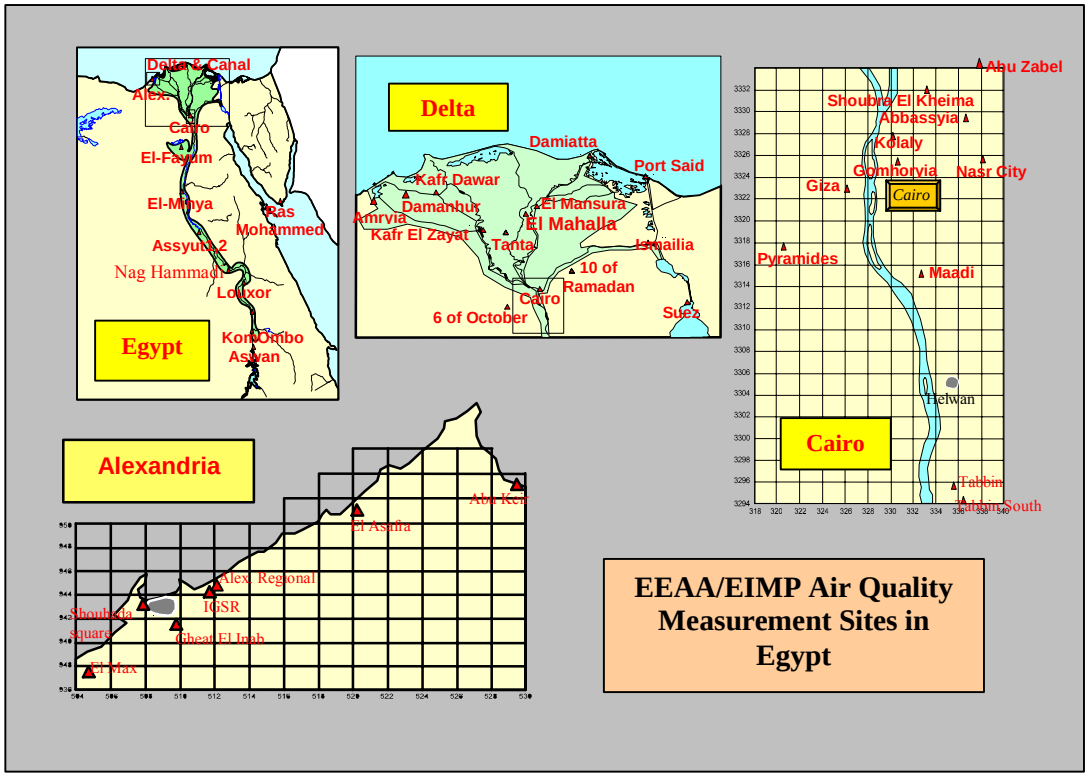

Figure 1: The EEAA/EIMP Air Quality Measurement Sites in Egypt

2.2 Indicators

A set of environmental indicators have been selected by the EIMP Programme to:

- Provide a general picture
- Be easy to interpret
- Respond to changes
- Provide international comparisons
- Allow development of trend analyses.

To enable a balanced interpretation of the measured data, the results are being compared to international and national Air Quality Limit values, Standards or guidelines (EEAA, 1994). The guidelines as given by World Health Organization include a selection of a few priority pollutants (WHO, 1987). The indicators selected by EIMP were:

- Sulphur dioxide (SO_2)
- Nitrogen dioxide (NO_2) and/or NOx (Nitrogen oxides),
- Total Suspended Particulate matter (TSP), or better PM_{10} (suspended particles with diameter less than 10 micrometer).
- Ozone (O_3)
- Carbon monoxide (CO)
- Lead (Pb)

Not all parameters are being measured by the EIMP/EEAA Programme at all sites. This depends on site specification and typical dominating sources in the

specific area. Also VOC (Volatile Organic Compounds) and Dust Fall are being measured in some sites in Egypt.

3. Air quality limit values

Air Quality Limit values are given in the Executive Regulations of the Environmental Law no. 4 of Egypt (EEAA, 1994). These Air Quality Limit values are presented in Table 2.

Table 2: Ambient Air Quality Limit values as given by Law no.4 for Egypt (1994) [1] compared to the World Health Organisation (WHO) air quality guideline values.

Pollutant	Averaging time	Maximum Limit Value	
		WHO	Egypt
Sulphur dioxide (SO_2)	1 hour	500 (10 min)	350
	24 hours	125	150
	Year	50	60
Nitrogen dioxide (NO_2)	1 hour	200	400
	24 hours	-	150
	Year	40-50	
Ozone (O_3)	1 hour	150-200	200
	8 hours	120	120
Carbon monoxide (CO)	1 hour	30 000	30 000
	8 hours	10 000	10 000
Black Smoke (BS)	24 hours	50 *	150
	Year	-	60
Total Suspended Particles (TSP)	24 hours	-	230
	Year	-	90
Particles <10 µm (PM_{10})	24 hours	70 **	70
Lead (Pb)	Year	0.5-1,0	1

* Together with SO_2 ** Norwegian Air Quality Limit value

Dust fall (DF), which are measured as part of the programme, have no Air Quality Limit value. However, some countries normally state that when dust fall values exceed 10 g/m^2 per 30 days, the area may be considered unclean (polluted).

4. Suspended dust

Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or black smoke. Others are so small that individually they can only be detected with an electron microscope. Some particles are directly emitted into the air. They come from a variety of sources such as cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, stone crushing, and burning of waste and wood.

Thoracic particles that may be transported to the lung after breathing is from a health point of view the most interesting indicator for ambient dust. These particles are less than 10 micrometer in diameter and are called PM_{10}. A part of

the PM_{10} is black smoke or soot most often originating from combustion. The total mass of suspended particles varies in size from the smallest sub micron particle to the larger particles up to about 50-100 micrometer in size. This total mass can only be measured by high volume samplers and is referred to as Total Suspended Particles (TSP).

4.1 Thoracic particles, (PM_{10})

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, and as seen from Figure 2, annual average concentrations ranged between 100 and 250 µg/m^3 in urban and residential areas and up to 450 µg/m^3 near industrial sites.

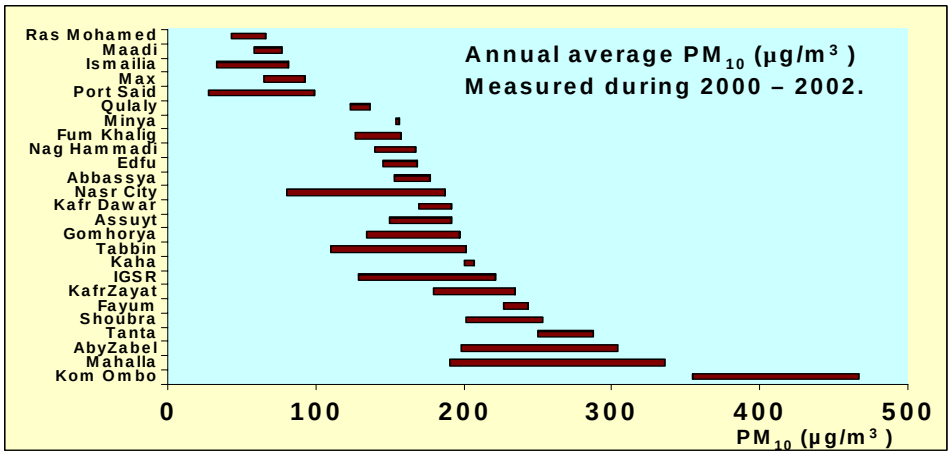

Figure 2: The range of annual average PM_{10} concentrations measured at 25 sites in Egypt (2000 - 2002).

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 were found in 2000 and 2001.

4.2 The background PM_{10} concentrations in Egypt

PM_{10} concentrations measured with different type of instruments; in different measurement programmes at a variety of sites and at different seasons indicate that the typical average background concentration of PM_{10} seems to be around 70 to 80 µg/m^3. (Sivertsen, 2003) A level of 70 µg/m^3 is equivalent to the Air Quality Limit value for 24-hour average PM_{10} concentrations as given by the Law no. 4 of Egypt.

These levels can be found also in areas where local anthropogenic sources do not impact the measurements. The “natural background” levels are thus assumed to be originating from wind generated dusts in the desert areas surrounding the large urban areas such as Cairo.

4.3 Black smoke (soot)

Also the black smoke concentrations are frequently found to exceed the Air Quality Limit value of 150 µg/m^3 as a 24-hour average concentration. Figure 2 presents the frequency of exceedance of the AQL value at five selected sites in Egypt.

At industrial sites such as in Kom Ombo (downwind from a sugar factory) and in the southern Tabbin area (brick factories) the black smoke concentrations were above the AQL value during 8 to 43 % of the time annually from 2000 to 2002.

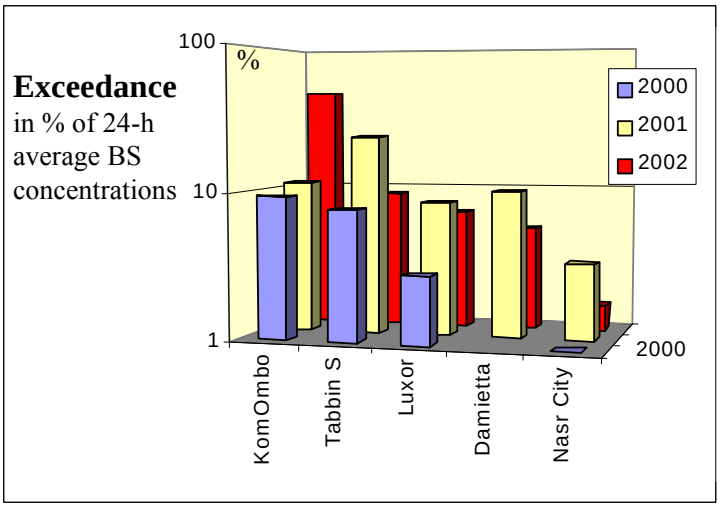

Figure 3: The frequency (in %) of exceeding the Air Quality Limit value of 150 µg/m^3 as daily average concentration at 5 selected sites in Egypt during 2000, 2001 and 2002.

Measurements of black smoke in Luxor, Damietta and in a street in Nasr City show that exceeding of the daily limit values occurred also at these sites (1 to 8 % of the time).

4.4 Total suspended particles (TSP)

The annual average TSP concentrations measured at 5 sites in Egypt from 2000 to 2002 is presented in Figure 4.

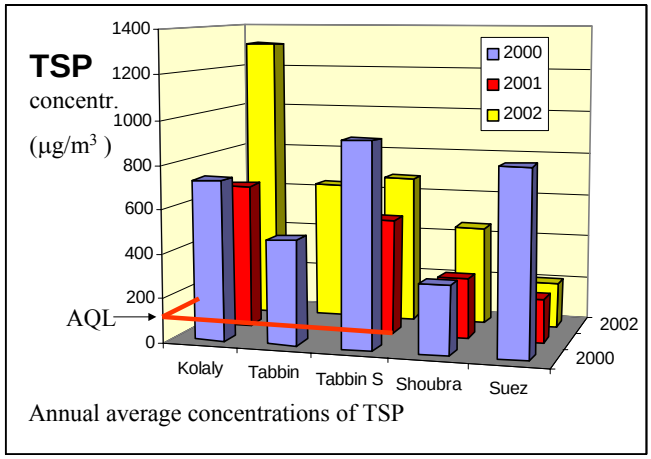

Figure 4: Annual average TSP concentrations measured in 2000, 2001 and 2002.

The Air Quality Limit (AQL) value for Egypt, 90 µg/m^3 as annual average, was exceeded at all sites. Sites surrounded by traffic, industries and high activity, such as Kolaly in Cairo city, Tabbin with cement factories and other industrial activities had very high TSP concentrations. At Suez there was a significant improvement in TSP concentrations when the bus station that surrounded the site moved out of the city.

High TSP concentrations may in many cases also be generated by wind blown dust, e.g. during the Khamsin period.

5. Sulphur dioxide (SO_2)

Sulphur dioxide, or SO_2, belongs to the family of sulphur oxide gases (SO_x). These gases dissolve easily in water. Sulphur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminium, copper, zinc, lead, and iron. SOx gases are formed when fuel-containing sulphur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals is extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulphates and other products that can be harmful to people and their environment.

The SO_2 concentrations measure at a variety of sites in Egypt occasionally exceed the AQL values as given by Law no. 4. SO_2 is, however, not an air pollution problem of the same magnitude in Egypt as suspended particles. The limit values are most often exceeded in or near industrial areas and in some few cases inside urban areas as in the Cairo city center. As an example the exceedances of the 24-hour average concentrations are presented for 5 sites in Figure5.

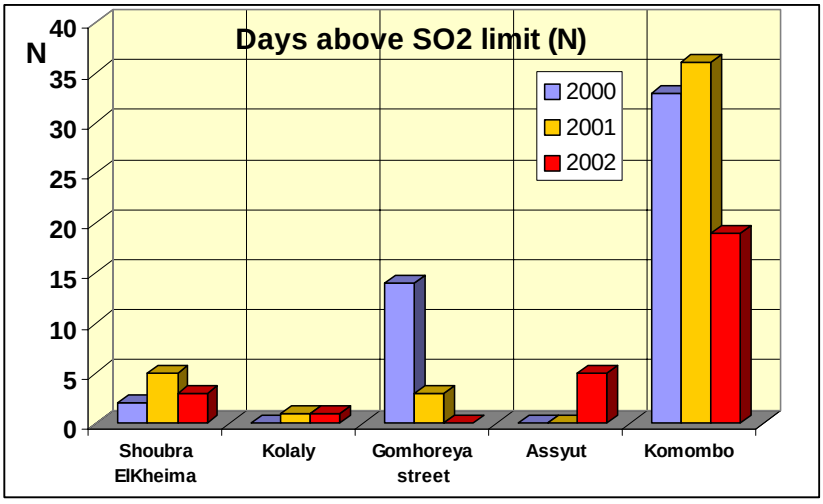

Figure 5: The number of days when the AQL values for SO_2 (24-h average) have been exceeded in 2000, 2001 and 2002 at 5 selected sites in Egypt.

Industrial areas like Shoubra ElKheima (several industries) and Kom Ombo (where the measurements are taken only 1 km downwind from a sugar factory) have revealed frequent exceeding of the limit values, while the urban stations inside Cairo only occasionally have exceeded the limit values. Also in Kafr Zayat and in the southern Tabbin area we have recorded the SO_2 concentrations to exceed the limit values.

The short-term concentrations given by the one-hour average concentrations are normally exceeded during less than 1 % of the time inside Cairo.

Annual average concentrations have been estimated from different type of measurements, and concentrations above AQL have been found in many areas and at several measurement sites. Long-term average concentrations estimated from passive sampling of SO_2 are presented in Figure 6.

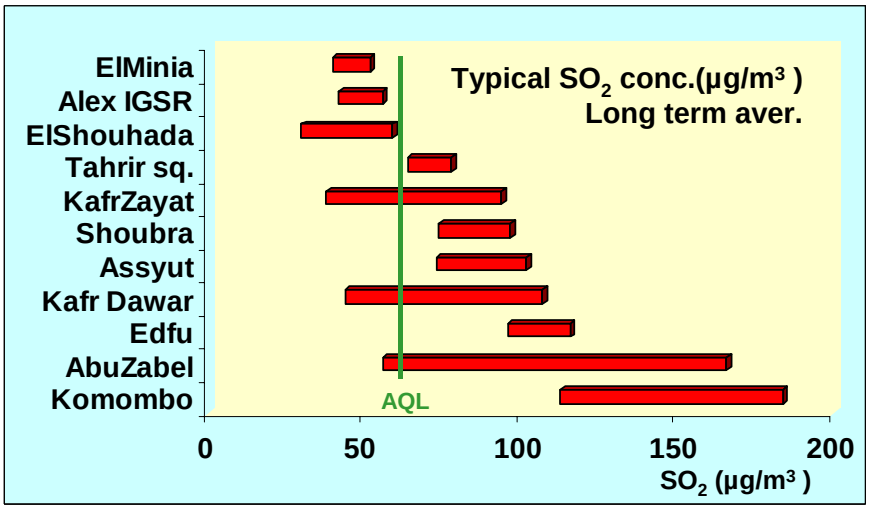

Figure 6: Typical ranges of long-term average (annual) concentrations of SO_2 measured by passive samplers at 11 selected sites in Egypt.

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.

6. Carbon Monoxide (CO)

CO is a component of motor vehicle exhaust. High levels of CO generally occur in areas with heavy traffic congestion. In cities, 85 to 95 percent of all CO emissions may come from motor vehicle exhaust. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing), residential waste and wood burning, and some natural sources such as forest fires.

Inside the city centre of Cairo traffic jam often occur and the typical daily average concentrations of CO thus will exceed the Air Quality Limit values.
Figure 7 indicates the frequency of exceedance of the 8-hour average concentration of 10 mg/m3

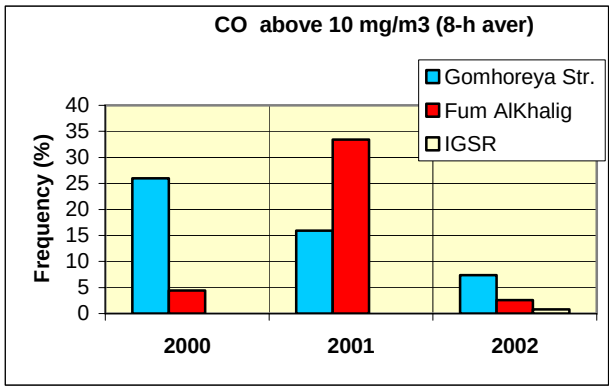

Figure 7: The occurrence of 8-hour average CO concentrations above the AQ limit value of 10 mg/m3 measured at one street canyon and two roadside stations.

In the streets of Cairo, such as around the old opera square (Gomhoreya street) and at some of the streets with high traffic density such as FumAlKhalig the daily 8-hour average CO concentration was exceeded in 5 to 33 % of the time.

The one-hour average limit value of 30 mg/m3 was rarely exceeded. This happened only during a few hours each year in the Gomhoreya street canyon.

7. Nitrogen dioxide (NO_2)

Nitrogen oxides, or NOx, are the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colourless and odourless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over the urban area.

Nitrogen oxides form when fuel is burned at high temperatures, as in a combustion process. The primary sources of NOx are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.

NO_2 is being measured by the EIMP programme at 22 sites in Egypt. Annual average concentrations 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.

The one-hour average limit value of 400 μg/m^3 was not exceeded in 2002. However, the 24-hour average limit value of 150 μg/m^3 was exceeded during one to five days in the streets of Cairo. Passive sampling data indicate that there may be other areas with high traffic density where the limit values occasionally were exceeded.

8. Ozone, (O_3)

Measurement data indicate that ground level ozone together with small particles is one of the major air pollution problems of Egypt. We therefore have to understand the formation and occurrence of ozone.

Ozone (O_3) at the surface is most often created by a chemical reaction between oxides of nitrogen and volatile organic compounds (VOC) in the presence of heat and sunlight.

VOC + NOx + Heat + Sunlight → Ozone

Ozone has the same chemical structure whether it occurs miles above the earth or at ground level and can be "good" or "bad," depending on its location in the atmosphere. In the earth's lower atmosphere, ground-level ozone is considered "bad." Motor vehicle exhaust and industrial emissions, gasoline vapours, and chemical solvents are some of the major sources of NO_x and VOC, which help to form ozone. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air.

In the greater Cairo area the transport time during hot summer days is long enough so that large amounts of harmful ozone is being created in the area. Afternoon maximum concentrations as recorded at Giza (Cairo University) and at a roof station at Abbaseya are typical examples of this kind of regional formation of ozone. Both these sites represent the kilometre scale urban areas away from local sources.

Figure 8 illustrates the annual average diurnal variation of ozone at 4 selected sites in Egypt.

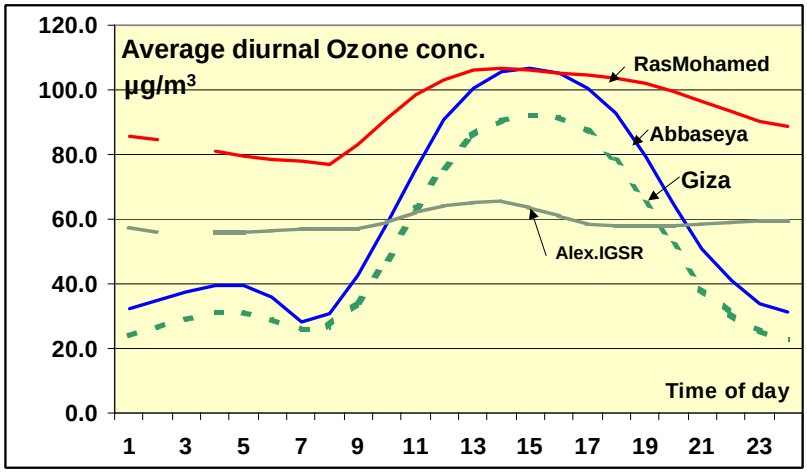

Figure 8: Annual average diurnal variation of ozone measured at 4 sites in Egypt 2000-2002.

The regional background measurements undertaken at Ras Mohamed at the southern tip of Sinai indicate that the background ozone level is on the average higher than the levels measured in Cairo and Alexandria. However at daytime during summer conditions the concentration levels that are reached in the greater Cairo area are higher than the maximum background concentrations. In the morning rush hours we see that the NOx emissions from cars are reducing the ozone by using ozone to form NO_2. The ozone concentrations therefore reach a minimum at about 08:30 in the morning.

Ozone may also be formed at far distances (tens to hundreds of kilometres) downwind from large cities like Cairo and Alexandria. From Cairo high concentrations may be found in the Nile valley south of the city. From Alexandria the maximum concentration may be found in the Delta.

At the measurement site itself in Alexandria we see from Figure 8 that the ozone levels are influenced by NOx emissions from traffic in the city. The "fresh" NOx emissions are "using" ozone. The concentrations are therefore relatively low as the site clearly is located inside the urban boundary layer.

The one-hour average concentrations rarely exceeded the Air Quality Limit value of 200 µg/m^3. These concentrations were exceeded during less than 1 % of the time.

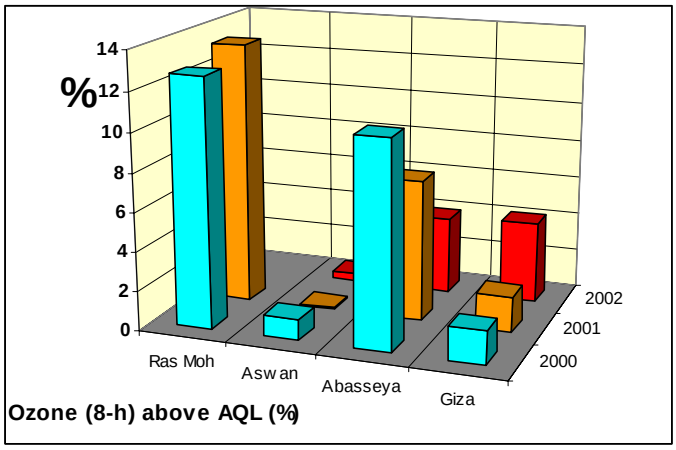

Figure 9: The frequency (%) of 8-hour average ozone concentrations exceeding the AQL of 120 µg/m^3.

The 8-hour average limit value (120 µg/m^3) however, was exceeded more frequently, as the relatively high ozone concentrations during the summer season seem to last for several hours.

At Ras Mohamed the 8-hour average concentration was exceeded during 13,4 % of the time in 2001, at Abbaseya 10,5 % of the time in 2000 and at Giza and Aswan up to about 4 % of the time. During the summer season exceedances are found more frequently.

9. Summary and conclusions

Suspended dust (measured as PM_{10} and TSP) is 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. Daily average concentrations of more than 6 times the Air Quality Limit value for Egypt are being recorded occasionally (2 to 3 % of the time) in the urban areas of Cairo. 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.

The concentration levels of SO_2 have also 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 in Cairo frequently exceeded the Air Quality Limit value. In the streets of Cairo, with high traffic density, the 8-hour average CO concentration, especially during daytime hours, was exceeded in 5 to 33 % of the time.

High concentrations of surface ozone have been observed as a result of regionally produced secondary pollutants in the Cairo region. Also the background

measurements of tropospheric ozone at Ras Mohamed, at the southern tip of Sinai, show high concentrations especially in the summer season. On an annual basis the 8-hour average limit value (120 μg/m^3) was exceeded in the urban area of Cairo; at Abbaseya 10,5 % of the time in 2000 and at Giza about 4 % of the time.

NO_2 is not a big problem in Egypt based on a rather high air quality limit value of 400 μg/m^3 as a one-hour average limit value. The 24-hour average limit value of 150 μg/m^3 , however, was exceeded during one to five days in the streets of Cairo.

10. References

Ahmed, H. (2003) Air Quality in Egypt, 2002. Cairo (Environmental Information and Monitoring Programme, EIMP report).

EEAA (1994) "Maximum limits for outdoor air pollutants" as given by Annex 5 of the Law number 4 for 1994, Law for the Environment, Egypt. Cairo, Egyptian Environmental Affairs Agency.

Rodes, C.E., Lawless, P.,A., Nasrallah, M. (1996) An assessment and source apportionment of airborne particulate matter in Cairo undertaken for the U.S. Agency for International Development. Presented in a meeting at NRC, Cairo 1996.

Sivertsen, B. (1999) DANIDA/EIMP. Air pollution in Egypt. Status after the first year of EEAA/EIMP measurements. Presented at the EEAA/EIMP Seminar on Air Pollution in Egypt, Maadi, 13 May 1999 (NILU OR 33/99).

Sivertsen, B. (1999) On-line air quality monitoring systems used in optimal abatement strategy planning. Presented at the International Conference on Environmental Management, Health and Sustainable Development, Alexandria, Egypt, 22-25 March 1999. Kjeller (NILU F 7/99).

Sivertsen, B. (2000) Understanding air quality measurements. Kjeller (NILU TR 4/2000).

Sivertsen, B. (2001). Passive sampling of SO_2 and NO_2 ambient air concentrations in Cairo. October 2000. Kjeller (NILU OR 16/2001).

Sivertsen, B. (2003) Background PM_{10} concentrations in Egypt. Cairo May 2003 (EIMP Memo dated 31 May 2003).

Sivertsen, B. and Dreiem, R. (2000) DANIDA/EIMP. Environmental Information and Monitoring Programme (EIMP). Air quality monitoring component. Mission 18 report. Kjeller (NILU OR 38/2000).

Sivertsen, B., El Seoud, A., Fathy,H., Ahmed, H. (2001) Air Pollution in Egypt. Presented at the 12th World Clean Air & Environment Congress, 26-31 August 2001, Seoul, Korea. Kjeller (NILU F 2/2001)

World Health Organization (1987) Air quality guidelines for Europe. Copenhagen (WHO regional publications. European series; No. 23).