Department of Natural Resources and Environment (DONRE)
Ho Chi Minh City

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Ho Chi Minh City Environmental Improvement Project
Air Quality Monitoring Component

The air quality monitoring and management system for HCMC, Vietnam

NILU
Norwegian Institute for Air Research

HEIA
Ho Chi Minh City
Environmental Improvement Project
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The air quality monitoring and management system for HCMC, Vietnam

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Summary

Ho Chi Minh City, HCMC, is the largest city in Vietnam with more than 5 million people living on an area of 2,056 km^2. Air pollution is a serious problem in HCMC. Emissions from vehicles, cars, trucks etc., and a large number of motorbikes is the most obvious source of air pollution. Even relatively new vehicles do not have modern technology. No pollution control and poor maintenance as well as low quality fuels are factors that result in high emission levels.

The main exposure and human health impact seem to stem from millions of motorbikes filling the streets from early morning to late night. Simple counting has indicated that several streets have more than hundred thousand motorbikes passing through the street every day. Many people are spending a considerable time of the day along the streets and roads.

To identify and assess the air pollution situation in HCMC and automatic air pollution monitoring and assessment system has been installed and is presently being operated by trained local experts. The key features of the system is the integrated approach that enables the user in a user friendly way to not only access measured data quickly, but also use the data directly in the assessment and in the planning of actions. The demand of the integrated system to enable monitoring, assessment, planning and forecasting has been and will be increasing in the future. The basic GIS based database and planning tool used in HCMC is based on the NILU developed AirQUIS system. This system has been installed and is being applied in several large urban areas worldwide.

The data collected through the automatic monitoring and telemetric network is being quality controlled and transferred for storage in the AirQUIS database. Statistical programmes for quality control and data representativeness are being used and an automatic air quality index (AQI) generator provides AQI values for traffic and for urban background microenvironments to be displayed on the information web site.

Air pollution dispersion models have also been installed as part of AirQUIS for HCMC. Templates and routines for emission inventories are presently being applied to collect emission data and the first model estimated have been presented. In the near future concentration estimates will be used to evaluate different source's relative importance to the total exposure, impact assessment and to perform optimal abatement planning.

The air quality monitoring and management system for HCMC, Vietnam

1 The air quality measurement programme

1.1 The sites

A total of 9 measurement sites using automatic monitors have been established in Ho Chi Minh City (HCMC). Four of the sites were supported by Danida and installed in 2000, while the remaining five sites have been supported by NORAD and were installed with the support from Norwegian Institute for Air Research (NILU) in 2002. The stations, site characteristics and locations are given in the Table 1 below.

Table 1: Air pollution measurement sites in HCMC, site characteristics and positions.

Stations				Indicators					UTM 84 N	
ID	Code	Name	Charact.	PM10	NO2	SO2	O3	CO	X coordin (m)	Y coordin (m)
1	DO	DOSTE	Traffic		X	X	X	X	684,430	1,192,220
2	HB	Hong Bang	Traffic		X		X	X	681,620	1,189,460
3	TD	Thu duc	Res/Ind		X	X			693,640	1,199,790
4	TS	Tan Son Hoa	Urb Bkg		X	X	X	X	682,830	1,193,930
5	TN	Thong Nhat	Traffic	X	X	X		X	680,690	1,193,530
6	BC	Binh Chanh	Traffic	X	X			X	674,500	1,183,000
7	ZO	Zoo	Urb Bkg	X	X		X		686,420	1,193,370
8	D2	District 2	Res/ind	X	X	X	X		691,160	1,193,510
9	QT	Quang Trung	Urb Bkg	X	X	X	X		677,940	1,200,080

A map of HCMC with the locations of the nine sites is presented in Figure 1.

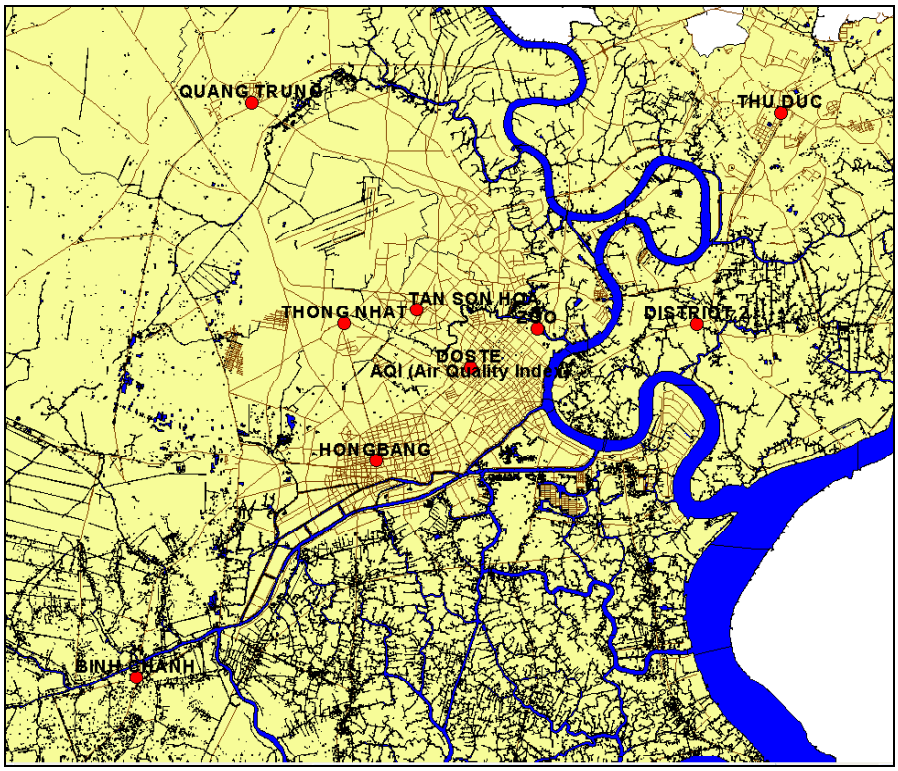

Figure 1: The location of the nine automatic air quality monitoring sites in HCMC.

The information provided by the air quality measurements are designed to:

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

1.2 Data quality control, QA/QC procedures

Quality assurance and quality control procedures implemented in HCMC follows international standards. Standard Operating Procedures (SOPs) have been prepared for DONRE/HEPA including station manuals for instrument installations, maintenance, calibrations and controls. All sites are visited and checked every week.

The daily control of the data is manually undertaken as soon as data have been retrieved at the Division of Environmental Quality, Monitoring and Assessment (EQMA) at HEPA: Data checks and data quality is being registered in a daily data validation manual. Whenever errors or strange data are identified from the

database, the field operators will have to be notified, so that errors in calibrations or in instrument performance can be checked and corrected as soon as possible.

1.3 Indicators

A set of environmental indicators have been selected by the HCMC air quality monitoring 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. The guidelines as given by World Health Organization include a selection of a few priority pollutants [11]. The indicators selected by the monitoring programme for HCMC were:

- Sulphur dioxide (SO_2)
- Nitrogen dioxide (NO_2) and/or NOx (Nitrogen oxides),
- Suspended particles with diameter less than 10 micrometer (PM_{10})
- Ozone (O_3)
- Carbon monoxide (CO)

2 Air quality limit values

Air Quality Limit values are given in the Vietnam standard TCVN 5937 – 1995. This standard specifies concentration of main constituents in ambient air and applies to carbon monoxide, nitrogen dioxide, sulphur dioxide, lead particulate, and total suspended particles. The standards further apply to evaluation of ambient air quality and to the monitoring of air pollution status.

The standards are presented in Table 2 together with the proposed World Health Organisation (WHO) Guideline values.

Table 2. Ambient Air Quality Standards (µg/m^3) for Vietnam compared to the World Health Organisation (WHO) air quality guideline values (WHO 2000)

Pollutant	Averaging time	Guideline and Limit Value	
		WHO	Vietnam
Sulphur dioxide (SO_2)	1 hour 24 hours Year	500 (10 min) 125 50	500 300 -
Nitrogen dioxide (NO_2)	1 hour 24 hours Year	200 - 40	400 100 -
Ozone (O_3)	1 hour 8 hours 24 hours	 120 	200 - 60
Carbon monoxide (CO)	1 hour 8 hours	30 000 10 000	40 000 10 000
Total Suspended Particles (TSP)	1 hour 24 hours Year	 - -	300 200 -
Particles <10 µm (PM_{10})	24 hours Year	50 1) 30	- -
Lead (Pb)	Year	0.5	5 (hourly)

1) EU Directives stage 1, 90 percentile

3 Suspended dust, the main problem

Suspended particulate matter seems to be the largest air pollution problem in HCMC when relating the levels to international guidelines and standards. TSP has been measured by high volume samplers and analysed gravimetric since 1995. PM_{10} has been measured at fixed station using beta gage type monitors since 2001.

3.1 TSP data

The concentrations of TSP were measured in the streets one hour ten times every month. From 1995 to 2000 ranged from 500 to 2000 µg/m^3. The highest concentrations were measured where Dien Bien Phu crosses Dinh Tien Hoang Street. An average concentration of more than 200 µg/m^3 was reported in 2000. This was a typical daytime value. From 2001 the concentrations were reduced to one third, due to change in traffic pattern and improvements of the road surface.

Figure 2 further shows that the TSP concentrations were about 500 µg/m^3 during the last two years.

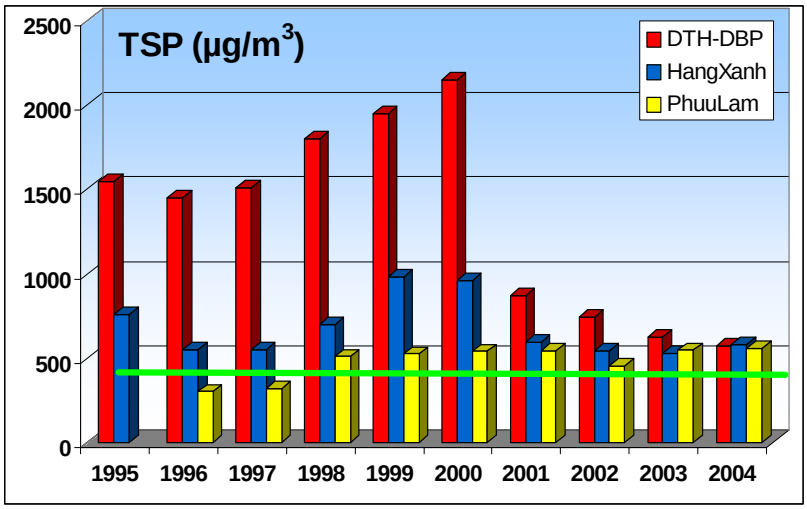

Figure 2: Total suspended particle (TSP) measurements in 3 streets of HCMC from 1995 to 2004.

Also the lead levels analysed at these TSP filters have been reduced from 1 – 2 µg/m^3 in 2001 to 0.5 µg/m^3 due to the introduction of unleaded gasoline in July 2001.

3.2 PM_{10} data

PM_{10} has been measured continuously since 2001. As of November 2004 five stations are giving reliable PM_{10} concentrations. Figure 3 shows that the typical annual average PM_{10} concentrations in HCMC from 50 to 130 µg/m^3.

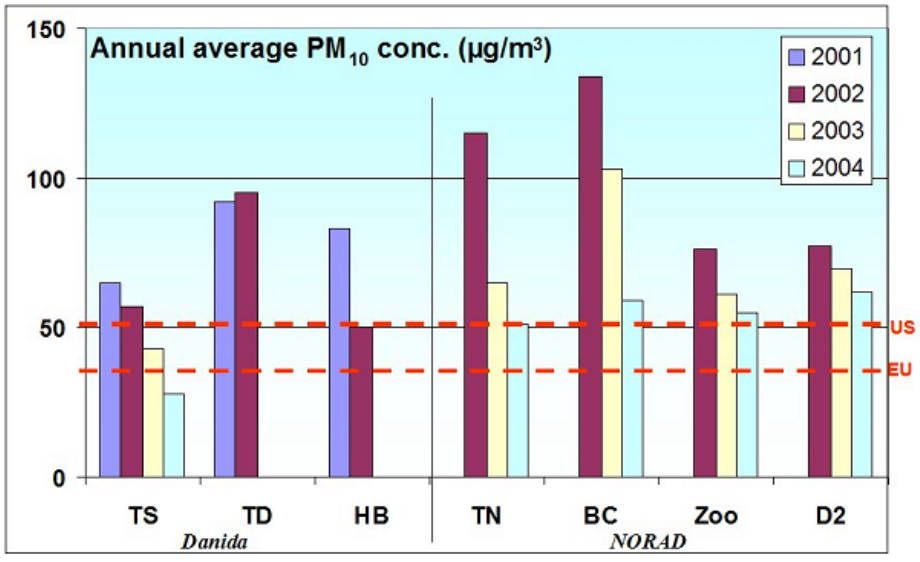

Figure 3: Annual average PM_{10} concentrations measured at 7 sites in HCMC.

The NORAD funded monitoring stations indicate that there has been a downward trend in average PM_{10} levels from 2002 to 2004. This may be caused by better

quality motorbikes and less emissions from the renewed motorbike park. The new generation Japanese bikes have less emission than the old Russian and Chinese bikes.

The measured levels have been verified by high volume samples of PM_{10} concentrations (Andersen type) at one site at DOSTE. The concentrations measured by this instrument and analysed gravimetrically was in accordance with the levels measured by monitors, as shown in Figure 4.

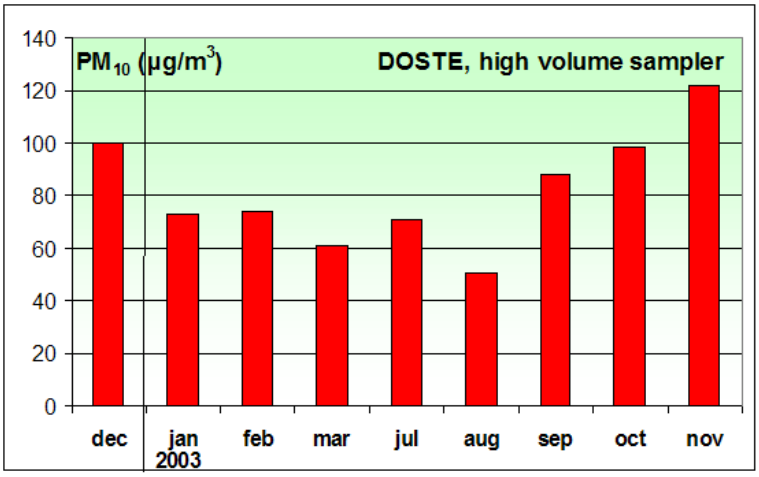

Figure 4: Monthly average PM_{10} concentrations measured by high volume sampling at DOSTE

Figure 4 also clearly shows that the average PM_{10} concentrations were higher in the dry season (November-January) than in the rainy season (July-August). During November 2003 the PM_{10} concentration was measured at 122 µg/m^3.

There is no air quality limit value for PM_{10} in the Vietnamese law. If we compare the measured 24-hour average concentrations with international limit values such as the EU limit of 50 µg/m^3 (98 percentile by 2010) or the USEPA standard of 150 µg/m^3, we will see that the PM_{10} concentrations measured in HCMC are exceeding these levels.

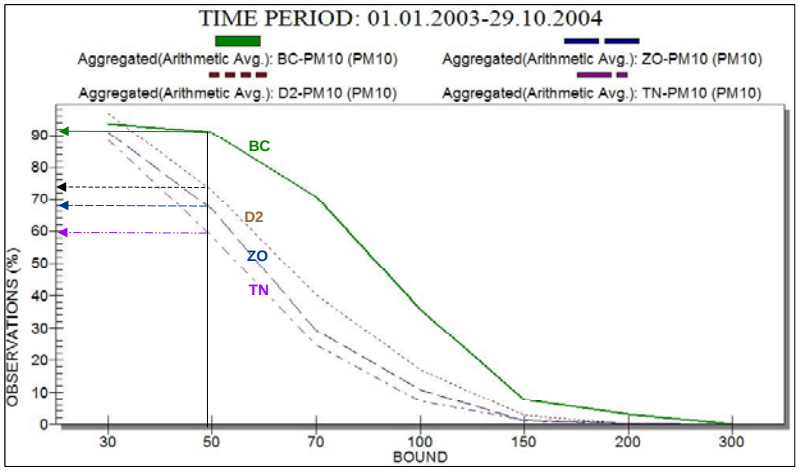

Figure 5: Cumulative frequency distribution of 24-hour average PM_{10} concentrations measured at 4 sites in HCMC (2003).

The US-EPA standard was exceeded only 1 to 10% of the time, while the EU Directive limit values were exceeded in 60 to 90 % of the time.

4 Ozone concentrations

Ozone is being measured at 6 sites in HCMC. The one-hour average concentration limit given by the Vietnamese law at 200 µg/m^3 is seldom exceeded. The 8-hour average concentrations as given by the World Health Organisation guideline values of 120 µg/m^3 are being exceeded as seen in Figure 6.

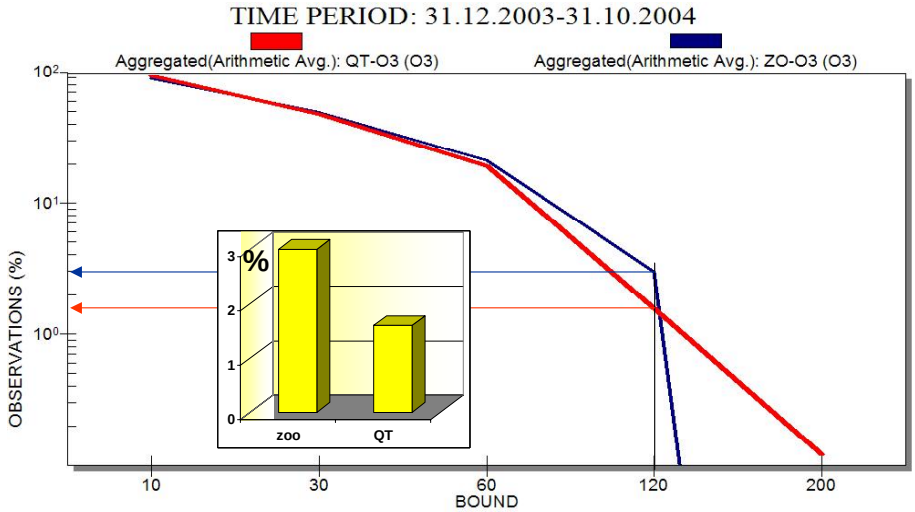

Figure 6: Cumulative frequency distributions of 8-hour average ozone concentrations measured at two urban background sites in HCMC, 2004.

On hot and dry days the daytime ozone concentration may reach levels exceeding 200 µg/m^3. Figure 7 illustrates such a day; 27 October 2004.

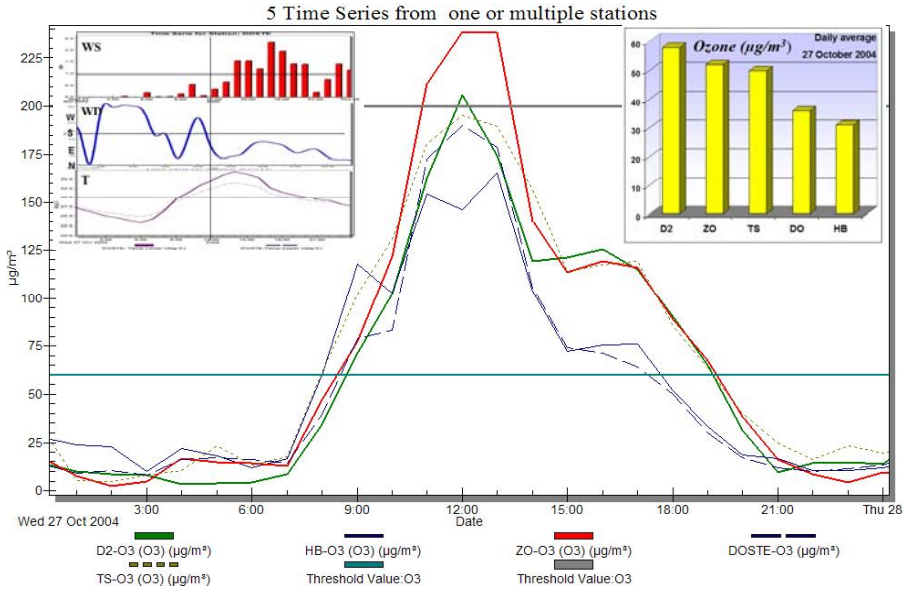

Figure 7: Hourly ozone concentration measured at 5 sites in HCMC on 27 October 2004. Daily average concentrations and meteorological conditions are also presented.

Ozone concentrations reach a maximum at all stations in HCMC around noontime. The average levels at the urban and residential background sites (D2, ZO) are significantly higher than at the roadside stations (DO, HB) as should be expected. The Vietnamese 24-hour standard level of 60 µg/m^3 was not exceeded at any of the stations.

There is also a clear seasonal variation in the general ozone levels in HCMC. The regional concentrations are significantly higher during the dry season than during the rainy season.

Figure 8: Average ozone concentrations based on daily averages and concentrations measured at 13:00 hrs during each month at an urban background site in HCMC, 2003.

The concentrations in November to January ranged from 50 to 150 µg/m^3, while the July-August concentrations ranged between 30 and 50 µg/m^3.

5 NO_2 concentration

The NO_2 concentrations measured in HCMC are surprisingly low compared to experiences from other large cities.

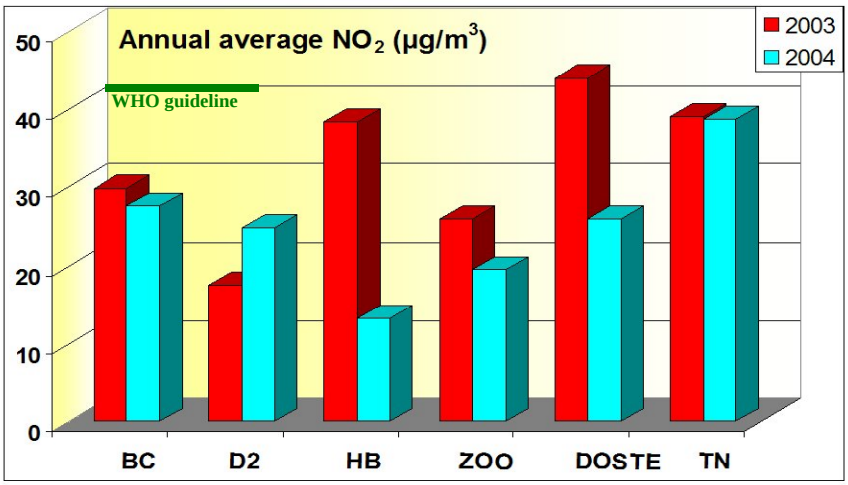

Figure 9: Annual average concentrations of NO_2 measured at 6 sites in HCMC, 2003-2004.

Typical annual average concentrations in 2003 and 2004 near roads and streets were around 40 µg/m^3. None of these stations are, however, located inside typical street canyons or on the sidewalk. The typical intakes are at 3 m above surface and about 5 m away from the curbside. Typical annual average NO_2 concentrations at urban background stations were 20 to 30 µg/m^3.

The one-hour average 99-percentile NO_2 concentrations ranged between 100 and 120 µg/m^3 at the roadside stations and between 40 and 60 µg/m^3 at the urban background stations. This is less than both the WHO guideline values and the EU Directives of 200 µg/m^3.

We have, however, seen that the NO_2 concentrations may vary significantly from the street and to only a few meters away from the street. Measurements undertaken using passive samplers indicate this as shown in Figure 10.

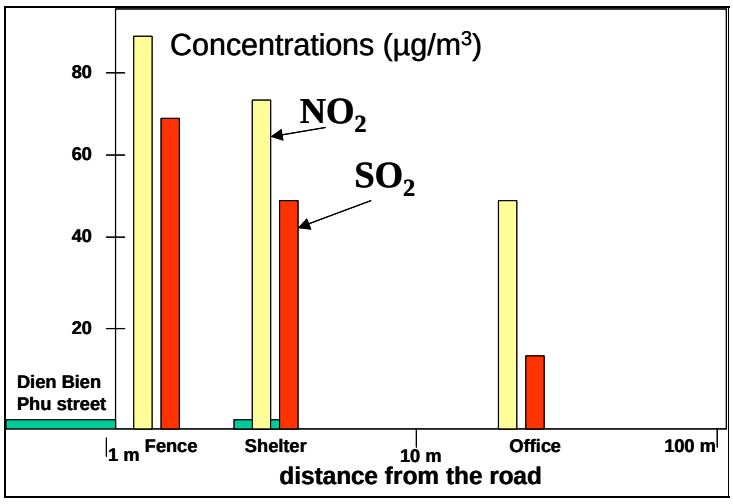

Figure 10: Two week average concentrations of NO_2 and SO_2 measured by passive samplers at 3 distances from Dien Bien Phu Street in HCMC. (Sivertsen, 2003)

The NO_2 concentration dropped from 86 µg/m^3 four meters from the curb side (fence) to 49 µg/m^3 at about 20 m from the street. The 40-50 µg/m^3 levels for NO_2 seem to be a typical long-term average concentration for the urban background in HCMC.

Manual measurements undertaken during daytime 10 times every month on the walkway also indicates that the concentrations here are higher than measured by the permanent network. The daytime measurements in the street typically range between 150 and 250 µg/m^3.

6 SO_2 concentrations

The SO_2 concentrations in HCMC as measured by the automatic network do not seem to be a major problem. Typical annual average concentrations at roadside stations vary from 25 to 45 µg/m^3. Emissions from diesel traffic inside the city

seem to be the major source for this SO_2. It has to be pointed out that none of the sites in operations presently are located directly downwind from major point sources such as power plants or smelters.

The typical annual average SO_2 concentrations at urban and regional background stations are about 15 to 25 µg/m^3.

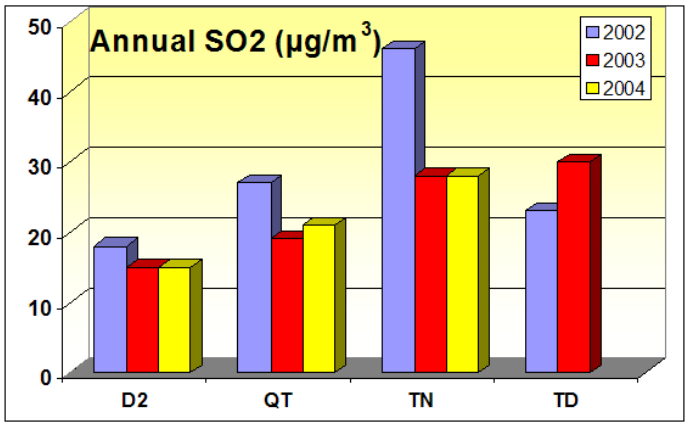

Figure 11: Annual average SO_2 concentrations measured at four sites in HCMC, 2002-2004.

The one-hour average 99 percentile concentrations are slightly less than 100 µg/m^3. The one-hour average concentrations at District 2 station occasionally reach between 150 and 200 µg/m^3 indicating that it may be influenced by narrow plumes from a power plant and from some industries located a few kilometres away from this site.

7 CO concentrations in streets

The high CO concentrations along roads and streets are closely linked to rush hour traffic and traffic congestions.

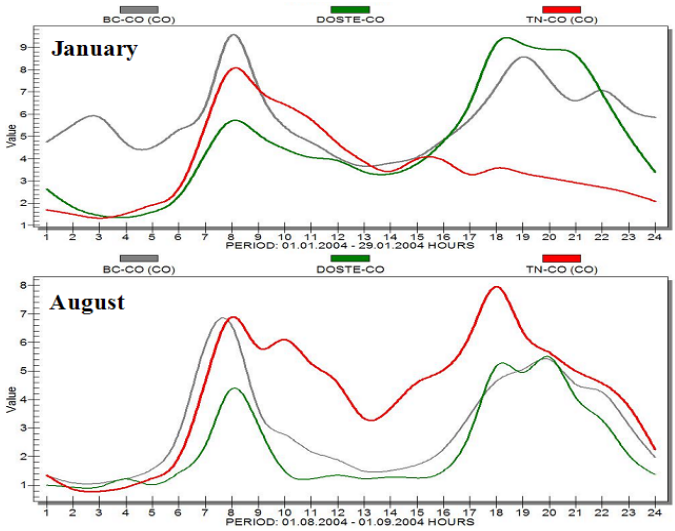

Figure 12: Average diurnal variation of CO concentrations measured at three roads in HCMC during January and August 2004.

The average maximum CO concentrations in the dry season (January) were slightly higher than during the wet season (August). The diurnal distribution also varied from one season to the other, which may be caused by changes in the meteorological conditions, related both to wind directions and stability conditions.

The 8-hour average concentrations at Thong Nhat station exceeded the limit value of 10 mg/m^3 in 0.9 % of the time during 2004.

8 Air Quality Management and planning

A GIS based air quality management and planning tool, AirQUIS, has been established at HEPA in HCMC. The system that was developed by NILU (AirQUIS, 2004) includes in addition to the measurement database an emission inventory system and advanced dispersion models.

The model results give spatial concentration distributions, which add information to the measurement data. The contribution to the pollution from different source categories, such as industry, traffic and domestic use can be calculated based on emission inventories. The emission inventory systems are part of the deliveries. In this way the system can be used as a tool for evaluating and comparing different measures to reduce air pollution.

8.1 Air quality index (AQI) generation

An example of the system used for automatic data retrieval, data presentation and generation of an air quality index, AQI (generated automatically), has been demonstrated in HCMC (Sivertsen and Thanh, 2004).

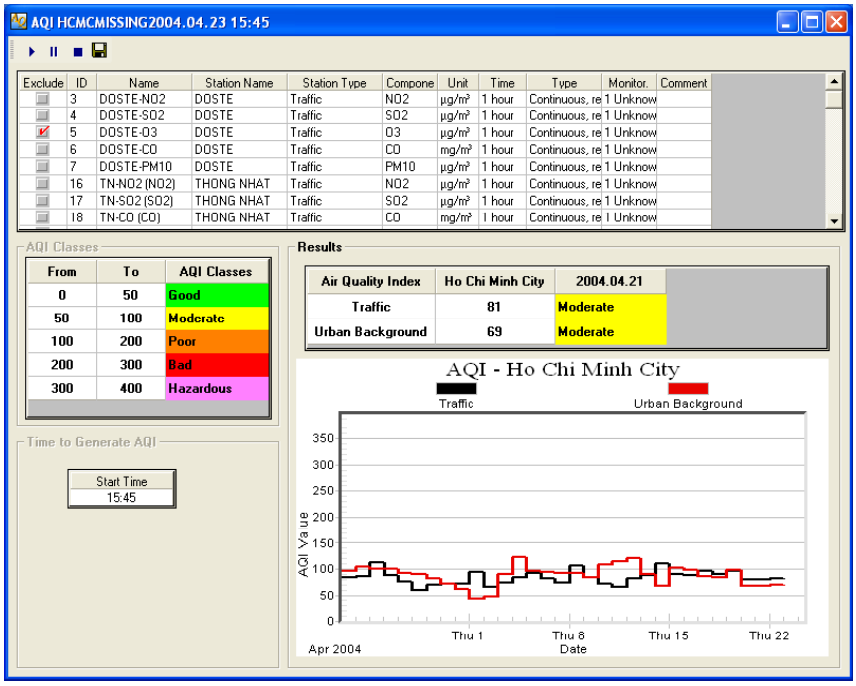

Figure 13: The AQI produced by the automatic system using AirQUIS

AQI takes the air quality data, which have been automatically quality assured, and produces a daily AQI for traffic and urban background environments. This information is now being prepared for dissemination via a Web application.

8.2 Dispersion and exposure modelling

Atmospheric dispersion models support the monitoring programme in HCMC. Templates for collection of necessary input data are provided by the AirQUIS system. These templates are being used to collect emission data from point sources area sources and line sources (traffic).

Traffic counting started in 2003. Road Nodes and Road Links were prepared for importing into AirQUIS. The traffic data that was counted by students in HCMC was modified to the templates. The emission factors of vehicle were based on the factors provided by NILU based on various projects performed in Asia.

The largest point sources have been identified and emission data were imported based on information collected by questionnaires to the industries. Plans are now being developed to identify industrial areas and parks to estimate the total emissions from these areas.

The first model estimates were performed based for daily average NO_2 concentrations as a result of emissions from 41 roads in HCMC produced by the AirQUIS models. Wind fields were generated from measurements at a 40 m tower. The results are presented in Figure 14.

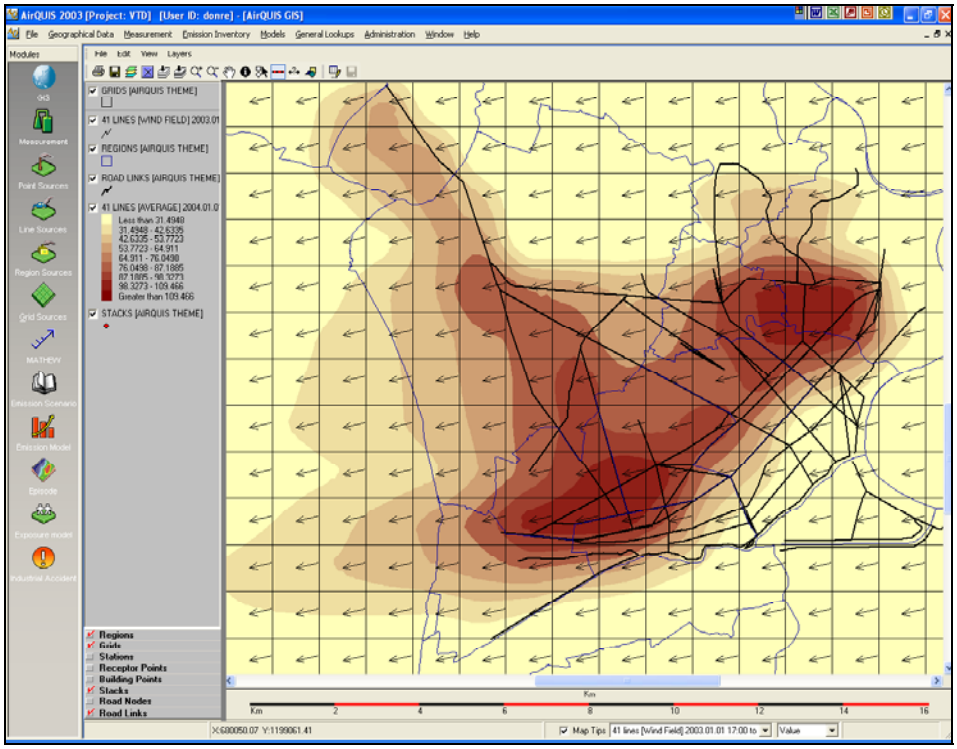

Figure 14: Dispersion modelling test for HCMC based on input of emissions from 41 roads in the city centre.

The built-in dispersion model system "EPISODE" (Gronskei et.al., 1993) (Slørdal et.al. 2003) is typically run on a 1 km-size grid system. These models have been tested and verified through several international inter comparison studies (Larssen et.al, 1994) and includes point source models, line source models and area source models.

The models may also be used for exposure estimates based on emission data, concentration distributions in a grid or in specified receptor points. Population distribution data for each Ward inside each of the District of HCMC has been collected for this purpose.

8.3 Abatement strategies

The final objective of the development in HCMC is to perform abatement strategy planning in the future. This work will represent a continuation of the assessment work. For optimal abatement strategies data on abatement costs as well as cost estimates for air quality impacts will have to be estimated.

Methods and procedures for continuing the modelling work into strategy planning is being prepared in the next phase of the project parallel to the collection of input data. Scenarios will have to be identified by the local HEPA experts, and much of the basic preparations will have to be the responsibility of the same experts based on training and methods provided by NILU.

9 Summary and conclusions

To identify and assess the air pollution situation in HCMC and automatic air pollution monitoring and assessment system has been installed and is presently being operated by trained local experts. The GIS based database and planning tool used in HCMC is based on the NILU developed AirQUIS system.

The system is presently being used to collect and store air quality data from nine automatic monitoring stations. QA/QC procedures are followed to assure good quality data. The conclusions from the measurements after 3 years of operations are:

- The main problem is suspended particles, and PM_{10} concentrations are frequently exceeding limit values
- High ozone concentrations have been observed on dry hot days, also exceeding international standards and limit values
- NO_2 concentrations seldom exceed limit values, but very high concentrations have been observed in and close to roads and streets
- Generally high concentrations of suspended particles and oxidised pollutants occur along streets and roads
- The Air Quality Index values as defined in HCMC seldom reach bad or hazardous level, but this is also dependent upon the definition of limit values
- 8-hour average CO concentrations exceed limit values during rush hours in several streets

The monitoring and management system established in HCMC will be used for future Environmental impact assessment and for air quality planning. The final goal is to develop models and modelling systems that will enable local experts to perform optimal abatement planning and develop an air quality action plan for HCMC.

An immediate application of the data and modelling results may be as part of a study of Air Quality and Health impact.

10 References

AirQUIS (2004) The ultimate software for air quality management. URL: http://www.nilu.no/airquis/.

Bøhler, T. and Sivertsen, B. (1998) A modern air quality management system used in Norway. Kjeller (NILU F 4/98).

Bøhler, T. and Sivertsen, B. (2004) An integrated air quality management system for sustainable development. Presented at Dubai International Conference on Atmospheric Pollution, 21-24 February 2004, Dubai, UAE. Kjeller (NILU F 4/2004).

Grønskei, K., Walker, S.-E. and Gram, F. (1993) Evaluation of a model for hourly spatial concentration distributions. *Atmos. Environ., 27B*, 105-120.

Khoa, L.V. (2002) Air Quality Management of Ho Chi Minh City. Presented at BAQ conference, Bangkok Thailand. URL: http://www.cse.polyu.edu.hk/~activi/BAQ2002/BAQ2002_files/Proceedings/Subworkshop2/sw2a-5Vo.pdf

Larssen, S., Grønskei, K.E., Gram, F., Hagen, L.O. and Walker, S.-E. (1994) Verification of urban scale time-dependent dispersion model with subgrid elements, in Oslo, Norway. In: *Air Pollution Modelling and its Application X*. Ed. by S.E. Gryning and M.M. Milan. New York, Plenum Press. pp.91-99.

Sivertsen, B. (2003) Passive sampling of NO_2 and SO_2 at selected sites in Ho Chi Minh City. November 2002. Kjeller (NILU O 15/2003).

Sivertsen, B. and Bøhler, T. (2000) On-line air quality management system for urban areas in Norway. Presented at "The air of our cities – it's everybody's business". Paris 16-18 February 2000. Kjeller (NILU F 4/2000).

Sivertsen, B. and Thanh, T.N. (2004) Ho Chi Minh City Environmental Improvement Project. Air Quality Monitoring Component. Mission 4, April 2004; Status report (QR7-9), Data assessment and training. Kjeller (NILU OR 51/2004).

Slørdal, L.H., Walker, S.-E. and Solberg, S. (2003) The urban air dispersion model EPISODE applied in AirQUIS 2003. Technical description. Kjeller (NILU TR 12/2003).

Vo Thanh Dam (2004) Application of IT in Environmental Management in HCMC. Presented at Workshop on ICT for Environment, Hanoi, August 2004.

World Health Organization (2000) Air quality guidelines for Europe, second edition. Copenhagen, WHO, Regional Office for Europe (WHO Regional Publications, European Series, No. 91).

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ABSTRACT
The GIS based database and planning tool AirQUIS has been installed at hEPA/DONRE in HoChiMinhCity and is being used for air quality monitoring and management.
The data collected through the automatic monitoring and telemetric network is being quality controlled and transferred for storage in the AirQUIS databases. Statistical programmes for quality control and data presentations are being used, and an automatic air quality index (AQI) generator provides AQI values for traffic and for urban background microenvironments to be displayed on the information web site. Air pollution dispersion models have also been installed as part of AirQUIS for HCMC. Templates and routines for emission inventories are presently being applied to collect emission data, and the first model estimated have been presented.
The main air pollution problem in HCMC is suspended particles, and PM_{10} concentrations are frequently exceeding limit values. Also high ozone concentrations have been observed on dry hot days exceeding international standards and limit values.

NORWEGIAN TITLE
Luftkvaliteten i Ho Chi Minh City, Vietnam

KEYWORDS		
Air quality	Monitoring	AQMS

ABSTRACT (in Norwegian)

** Classification*
A Unclassified (can be ordered from NILU)
B Restricted distribution
C Classified (not to be distributed)