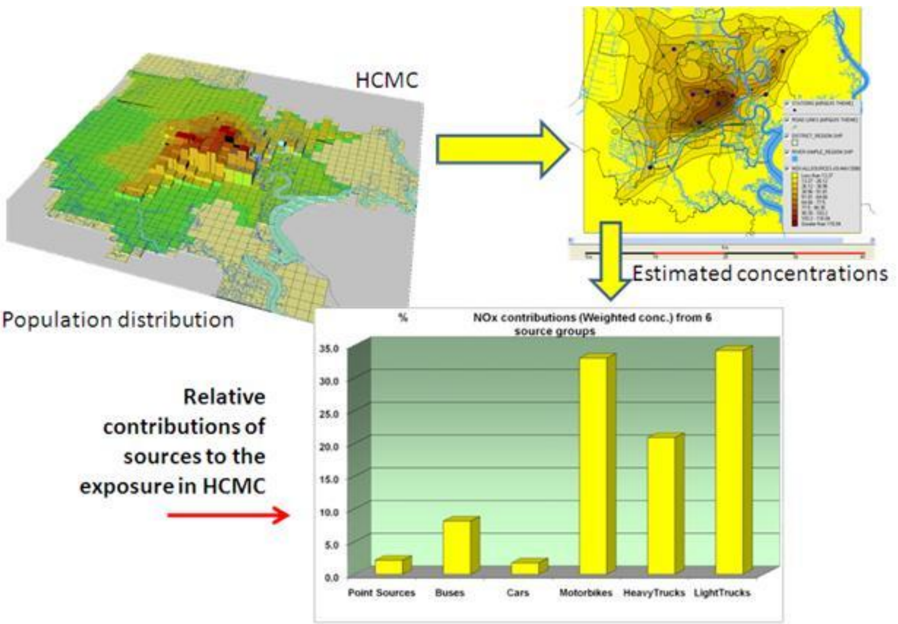
NILU: F 21/2008
REFERENCE: A-404
DATE: OCTOBER 2008

The relative importance of air pollution sources to the population exposure in HCMC, Vietnam

Bjarne Sivertsen
Vo Thanh Dam



Presented at:
BAQ, 2008
Bangkok, Thailand
12-14 November 2008

Presentation for BAQ 2008: 12-14 NOVEMBER 2008, BANGKOK, THAILAND

The relative importance of air pollution sources to the population exposure in HCMC, Vietnam

Bjarne Sivertsen. and Vo Thanh Dam.

Norwegian Institute for Air Research (NILU), www.nilu.no

Abstract:

Emissions from vehicles, cars, trucks, industries and home cooking are potential sources for air pollution in Hochiminh City (HCMC) Vietnam. Many of the sources have limited air emission control systems as well as poor maintenance.

A "bottom-up" detailed emission inventory has been developed for HCMC based on the NILU developed AirQUIS emission model. Evaluations of emission factors for some of the sources have been important in the total evaluation process. Dispersion models linked to population distribution information were used to estimate the exposure to people from individual source groups. The relative importance of the different sources has further been estimated based on total exposure evaluations.

The results indicate that heavy traffic and trucks are contributing to the total population exposure to a larger extent than anticipated from the distribution of vehicles. Based on the total traffic work performed by different types of vehicles, we have also estimated the relative importance of greenhouse gas emissions from the different sources in HCMC.

Keywords: Emission inventories, Modelling, Exposure, Green house gas emissions

Introduction

The Ho Chi Minh City Environmental Protection Agency (HEPA) under DONRE is operating an air quality monitoring and assessment system in HCMC. Air pollution dispersion models have been installed as part of the GIS based database and planning tool. This system is based on the NILU developed AirQUIS system (AirQUIS, 2004) (Slørdal et.al 2008).

Emissions from vehicles, cars, trucks, industries and home cooking are potential sources for air pollution in Ho Chi Minh City (HCMC) Vietnam. Many of the sources have limited air emission control systems as well as poor maintenance. A "bottom-up" detailed emission inventory has been developed for HCMC based on the NILU developed AirQUIS emission model. Evaluations of emission factors for some of the sources have been important in the total evaluation process.

In order to test and verify the dispersion models in AirQUIS measurement data for meteorology and air quality have been selected based on measurements performed in HCMC during 2007. Different periods have been tested, and the aim has been to present the model performance for a variety of dispersion conditions, dispersion parameterisation and different application modules for the use of the model features.

The dispersion models linked to population distribution have then been applied to estimate the exposure to people from individual source groups.

The model system

The model system, which is part of AirQUIS include an emission model, a wind field model and dispersion models for point- and line sources as well as models for exposure estimates..

- Emission model
  Calculates hourly emissions from area-, line- and point- sources. Stores results as field, line or point data set

- The wind field model
  Calculates 3-dimensional hourly wind fields from measurements of wind speed and direction, temperature and vertical temperature gradient and topography

- Dispersion model (EPISODE)
  Calculates hourly concentrations of pollutants in fields, points and along roads

- Exposure model
  Combines air pollution concentrations with population distribution in order to calculate exceedances of air pollution limit values.

The dispersion model combines 3D Eulerian and Lagrangian models to solve the atmospheric (mass) conservation equation in a 3D Eulerian grid. It contains separate sub-grid models for line and point sources. The model also contains a simple photochemical equilibrium model for NO, NO_2 and O_3. The output is normally hourly ground level concentrations.

Model test and verification

The dispersion models were tested and verified against measured concentrations in HCMC. A number of different tests and some modifications of input parameters were implemented in order to make the model results acceptable before the final selection for model applications in HCMC was decided upon.

The sensitivity in varying the wind field layer height and implementing different dispersion parameters were studied (Vo and Sivertsen, 2008). The estimated NOx concentrations in the receptor point at the measurement site Doste followed largely the measured concentration distribution in time, even if some of the peak values did not match exact at the right hour. The correlation coefficient was often quite low. However, the average level of model estimated concentrations are close to that measured. The kilometre scale grid average concentrations were lower than the receptor point concentration, which was to be expected. These average concentrations matched the measured concentrations well.

The final model concept was tested for different data periods and the results from August 2006 and February 2007 are shown in Figure 1.

The model results have also been verified using data from other stations in HCMC. As the average concentrations match the measured NOx concentrations well, this version of the model has been used to estimate long term (monthly and annual) average impact of pollution. Estimated impact based on 2006 data and the impact of mitigation measures in HCMC due to emissions of NOx have been based on the selected version of the model.

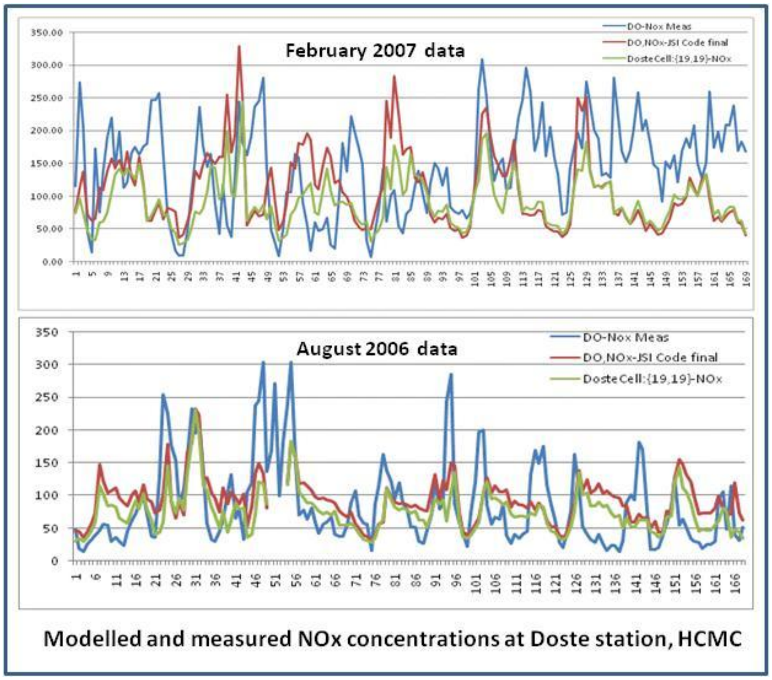


Figure 1: Model estimated NOx concentrations at Doste monitoring site using final input data concerning boundary layer parameterisation and model layers (red curve) versus measured concentrations (blue line). The green line shows the model estimated average km-scale grid cell concentrations.

Relative contribution of emissions from different vehicles

The model was first used to estimate the relative contribution to the concentrations measured in selected receptor points. The results from these estimates performed at the Doste station is presented in Figure 2.

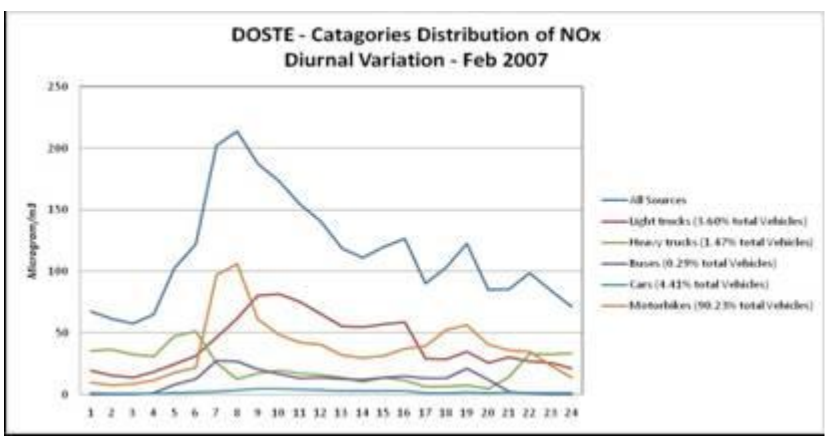


Figure2: The average diurnal variation of NOx concentrations at Doste presented for 5 vehicle classes and for the total traffic flow (February 2007).

The highest concentrations of NOx were estimated during the morning rush hour around 08:00 hrs. The main sources during these hours are light trucks and motor bikes. The most distinct time variation, demonstrating the importance of the rush hours, is shown in the contribution from motor bike emissions. The main contributions from light trucks are clearly a day time phenomenon.

The contributions from heavy trucks are only significant during night time hours between 21:00 and 07:00 hrs. The reason for this is that heavy trucks are not allowed on these roads during day time.

Exposure estimates

Based on data for the population distribution in HCMC we have estimated the number of people exposed to concentrations above given limit values. The results of these estimates for the 2006 emission scenario in HCMC is presented in Figure 3.

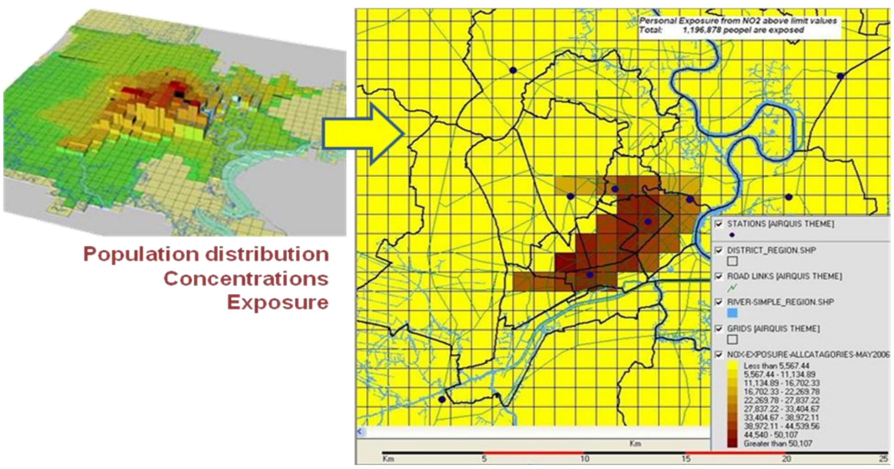


Figure 3: The number of people in 2006 in each square kilometre of the city exposed to NO_2 concentrations exceeding the Vietnam limit values

Assuming the emissions as given for 2006 a total of 1,197 million people are living in areas where the NO_2 concentrations may be exceeded.

Relative importance of the NOx exposure

The relative importance of different sources to the total population exposure in HCMC has been based on person-weighted average concentrations (PW) calculated by the following formula:

$C\ (PW) = \{ \Sigma\ (N(x,y) * C(x,y,i)\ )\} / N(tot)$

where N represents the total number of persons in the area (x,y).

C(x,y,i) represents the average concentration of compound i in area (x,y).

The NOx concentrations calculated as annual average concentrations in each square kilometre of HCMC are taken as input to these estimates. The highest average concentrations of NOx were estimated over the city centre. In the maximum impact area the average concentrations exceeded 100 $\mu g/m^3$. Concentrations higher than 50 $\mu g/m^3$ covered an area of about 50 km^2.

Data on the population distribution over HCMC together with estimated average concentrations of NOx were used to estimate person weighted average impact from the different groups of sources in HCMC. The relative importance of these sources is presented in Figure 4.

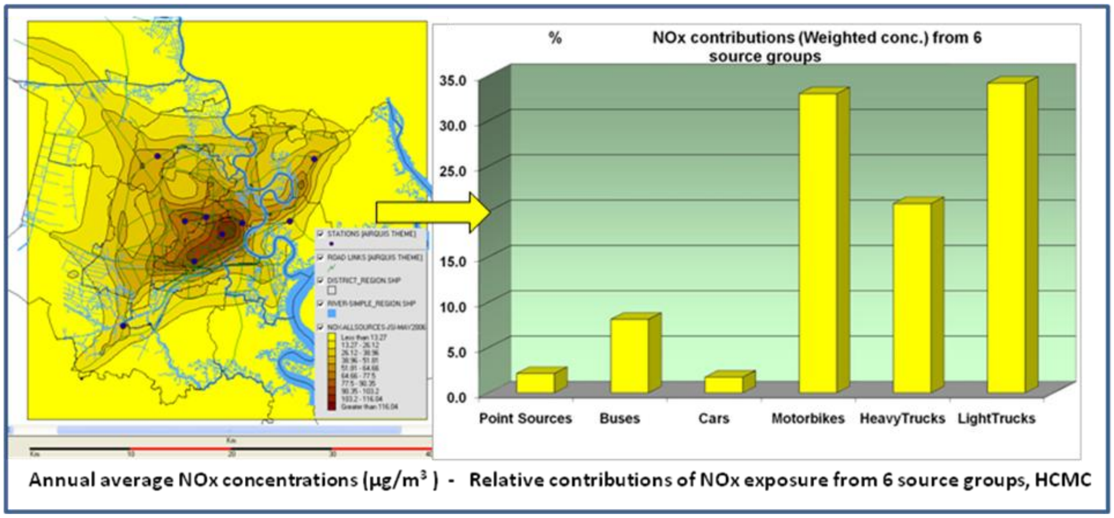


Figure 4: Population distribution and NOx concentration distributions from model estimates represented the input for estimating the relative contributions of sources to the exposure of NOx in HCMC.

These estimates show that about 32% of the contribution to the NOx exposure is due to emissions for motorbikes in HCMC. Another 33% of the contributions are from light trucks and 20 % is from heavy trucks.

Emissions from buses represent 20% of the exposure, while cars and point sources (industries) only represented less than 2 % each inside the city centre of HCMC.

Emission scenarios

It was evident from our estimates that the most effective measures to implement in order to reduce the air pollution impact in HCMC would be to look at the emissions from motor bikes and light trucks. Three scenarios were studied with different emission standards for NOx . The baseline pre 2004 emission conditions have been based on previous studies reported in Asia (Sivertsen and Dudek, 2006) (Suksod, 2001). One challenge in setting emission factors is that these factors used in the different studies in Asia may vary considerably (Khaliquzzaman, 2005). Also the vehicle class distribution may vary. Our baseline numbers are taken from field studies and traffic counting performed in HCMC (Sivertsen and Vo D.T, 2007).

The Government Decision 249/2005/QD-YTTg of October 2005 in Vietnam stated that all vehicles; trucks, cars and motorbikes, either built in Vietnam or imported had to apply the equivalent of Euro-2 standards from July 2005. This was the basis for estimating emission factors for Scenario 2; base year 2006. The discussions concerning the application of Euro1 to Euro3 standards being enforced July 2006 made it difficult to exactly specify NOx emission factors.

For future emissions, relevant for 2010, we have used emission factors as used in studies in Europe (Slørdal et.al 2006) and vehicle class distributions assumed to meet the Vietnam Government Decisions. The emission scenarios are presented in the following Figure 5.

	Emission factors (EF) NOx					
	pre 2004		2006		Future	
Vehicle class	% distr.	EF (NOx)	% distr.	EF (NOx)	%distrr.	EF (NOx)
Motor cycles (4s)	100	0.3	100	0.23	100	0.23
Pre Cat cars	25	2	10	2	0	2
Gasoline car, US83/87/90	10	0.2	10	0.17	5	0.17
Gasoline car, EURO 1G	20	0.8	20	0.14	5	0.14
Gasoline car, EURO 2G	15	0.3	15	0.09	5	0.09
Gasoline car, EURO 3G	0	0.1	5	0.06	60	0.06
Diesel cars, EURO 1D	20	1	20	0.33	0	0.33
Diesel cars, EURO 2D	5	0.5	5	0.24	5	0.24
Diesel cars, EURO 3D	5	0.5	5	0.15	20	0.15
Light truck, DHLL E1	50	4	50	3.2	30	3.2
Light truck, DHLM, E1	30	5	30	4.185	20	4.1
Light truck, DHLL E2	10	3	10	2.45	30	2.4
Light truck, DHLM, E2	10	5	10	3.171	20	3.1
Heavy trucks, DHLH E1	100	8.5	100	8.12	100	8.1
Buses DHB E1	100	8	100	7.844	100	7.8

Figure 5: Three emission scenarios for NOx emissions in HCMC with estimated vehicle class distributions and emission factors for NOx emissions.

Reduced exposure

The total population exposure has been estimated for the three scenarios. The pre-2004 situation and a future situation (2010) is presented in Figure 6.

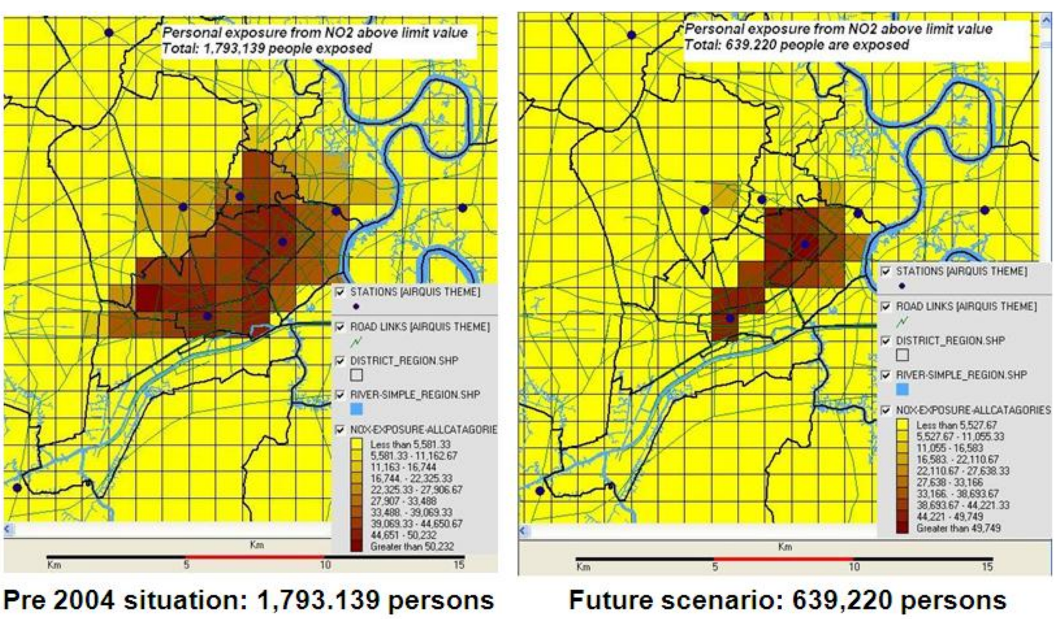
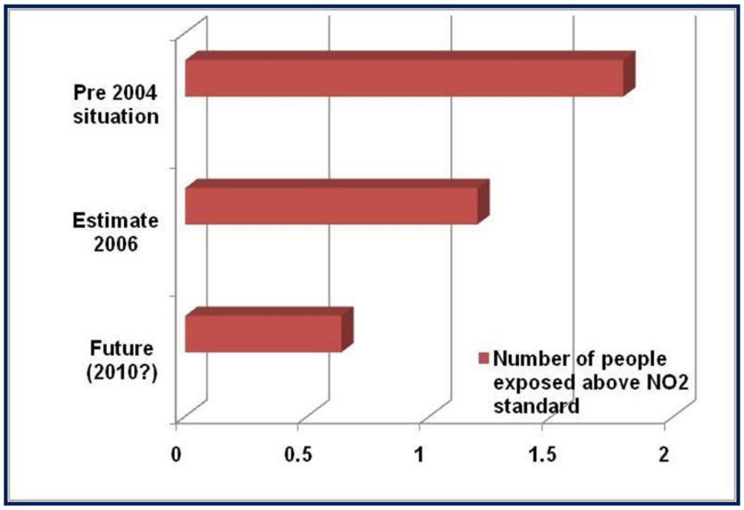


Figure 6: Total number of people exposed to NO_2 concentrations above the Vietnam limit values as given in TCVN (2005)

These findings indicate that strong traffic-oriented measures are needed in order to reduce the exposure of air pollution in HCMC. In summary the number of people exposed to NO_2 concantrations above the Vietnam standards are presented in Figure 7



Estimated CO_2 emissions for HCMC

Vehicle class	EF CO2	Distance	Vehicles	CO2 emissions
	(g/km)	(km/year)	N	(tons/yr)
Motor cycles (4s)	15	14500	3500000	761250
Gasoline cars	180	18000	150000	486000
Diesel cars	150	18500	60000	166500
Light trucks	220	19700	140000	606760
Heavy trucks	400	20000	300	2400
Buses	360	50000	3200	57600
All vehicles				**2080510**

The change in CO_2 emissions will not be significant up till year 2010 as it is expected that the increase in traffic flow will compensate for the relative small decrease in emissions of CO_2 from vehicles Euro2 to Euro4 classes.

Concluding remarks

The source contributors should be interpreted with caution. There are considerable uncertainties in the emission inventories, and these uncertainties will naturally influence the estimation of the various source contributions. Despite these difficulties, this type of model system represents an important tool in assessing present and future urban air quality. Recalculations with prescribed changes in emissions can give valuable information on the qualitative effect of various types of abatement measures and provide cost-saving support for decision makers.

References

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

Khaliquzzaman M. (2005) Emission Inventory for Motor Vehicle Fleet in Dhaka.URL: http://www.cleanairnet.org/caiasia/1412/articles-70581_v27a.pdf

Sivertsen, B., Thanh, T.N., Le, K.V. and Vo, D.T. (2004) The air quality monitoring and management system for HCMC, Vietnam, Presented at the Better Air Quality Conference, Agra, India, December 2004.
URL: http://www.cleanairnet.org/baq2004/1527/article-59135.html

Sivertsen, B., Thanh, T.N., Le, K.V. and Vo, D.T. (2005a). The air quality monitoring and management system for HCMC, Vietnam. Kjeller (NILU OR 1/2005).

Sivertsen, B., Thanh, T.N. and Willoch. H. (2005b) Ho Chi Minh City Environmental Improvement Project. Air quality monitoring and reference laboratory. Mission 6, May 2005, Status Report (MR1-2). Station audits, design reference laboratory and training. Kjeller (NILU OR 38/2005).

Sivertsen B. and Dudek A. (2006) Modelling air pollution in Hanoi. Support for the Review of Air Quality Management Sub-component for the Hanoi Urban Transport and Development Project. Kjeller (NILU: OR 83/2006)

Sivertsen, B., Thanh, T.N. (2006). Modelling air quality in Ho Chi Minh City, Vietnam. Presented at the Better Air Quality Conference, Yogiakarta, Indonesia, December 2006. URL: http://www.cleanairnet.org/caiasia/1412/article-71451.html

Sivertsen, B., Vo D.T. (2007). Emission Inventory and Air Quality Modelling in Ho Chi Minh City, Vietnam. Presented at the International Conference on Air Quality Management in South East Asia. Ho Chi Minh City, 21-23 November 2007. (NILU F 48/2007)

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).

Slørdal L.H., Mc Innes H., Laupsa H. and Sam Erik Walker (2006) Dispersion and exposure calculation of PM_{10}, NO_2 and benzene for Oslo and Trondheim for the year 2005. Kjeller. (NILU OR 90/2006)

Slørdal, L.H., McInnes, H. and Krognes, T. (2008) The Air Quality Information System AirQUIS. Information Technologies in Environmental Engineering, vol. 1, 40-47.

Suksod Janejob (2001) Automotive Emission in Thailand. Present at Regional Workshop “Reduction of Emission from 2-3 Wheelers” . September 5-7, 2001, Hanoi, Viet Nam.

TCVN (2005) Air quality. Ambient air quality standards. Ha Noi, Directorate for Stanr0ds and Quality (TCVN 5937-2005).

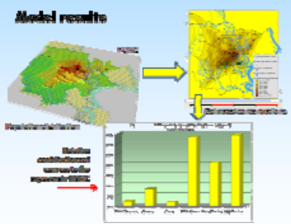
WHO (2005) Air quality guidelines, Global update 2005. Copenhagen, WHO, Regional Office for Europe. URL: http://www.euro.who.int/air/activities/20050222_2

Vo T. D. and Sivertsen B. (2008) Model test for applying AirQUIS in Ho Chi Minh City. Kjeller. (NILU OR 35/2008) http://www.nilu.no/index.cfm?ac=publications&folder_id=4309&publication_id=21131&view=rep

Appendix A

Presentation

The relative importance of air pollution sources to the population exposure in HCMC, Vietnam



Bjarne Sivertsen
Vo Thanh Dam

BAQ, 2008
Bangkok, Thailand
12-14 November 2008

Norwegian Institute for Air Research

Goal: Clean air in HCMC

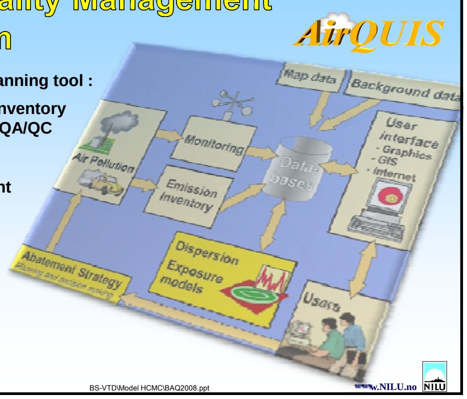
- ✓ Develop and verify adequate models
- ✓ Estimate exposure; present and future
- ✓ Assess relative importance of sources
- ✓ Evaluate impact of mitigation options

Air Quality Management System

AirQUIS

Integrated planning tool :

- Emission inventory
- AQ data & QA/QC
- Statistics
- Models
- Assessment
- Planning



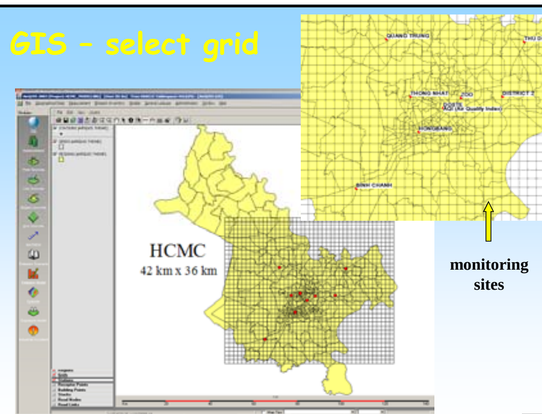
Models available in AirQUIS

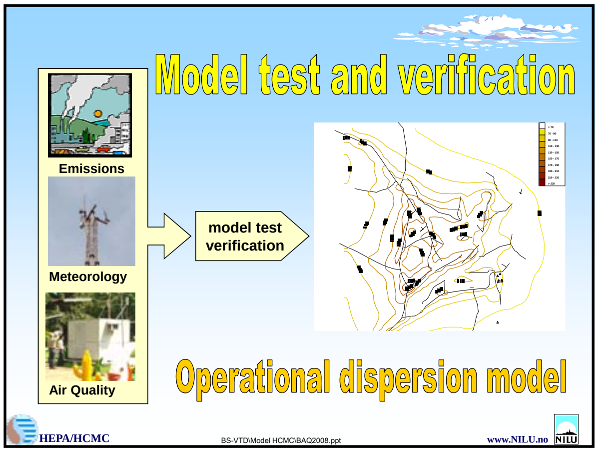
- **Emission model**
  - Calculates hourly emissions from area-, line- and point- sources. Stores results as field, line or point data set
- **Wind field model**
  - Calculates 3-dimensional hourly wind fields from measurements of wind speed and direction, temperature and vertical temperature gradient and a topography field
- **Dispersion model** (EPISODE)
  - Calculates hourly and half hourly concentrations of pollutants in fields, points and along roads
- **Exposure model**
  - Combines air pollution concentrations with population distribution in order to calculate exceedances

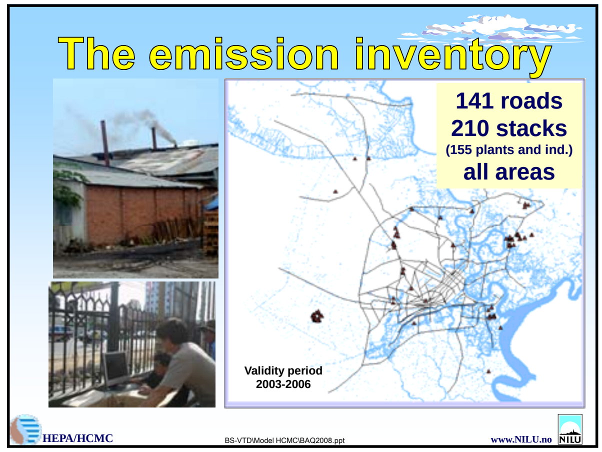
The AirQUIS "EPISODE" models

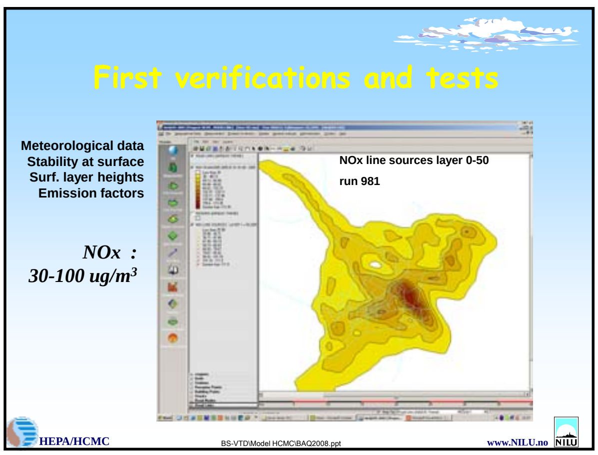
- A combined 3D Eulerian/Lagrangian model
- Solves the atmospheric (mass) conservation equation in a 3D Eulerian grid
- Contains separate sub-grid models for line and point sources
- Contains a simple photochemical equilibrium model for NO, NO_2 and O_3 (default)
- Contains a complete photochemical scheme for industrial and urban areas (optional)
- Calculates ground level hourly concentrations

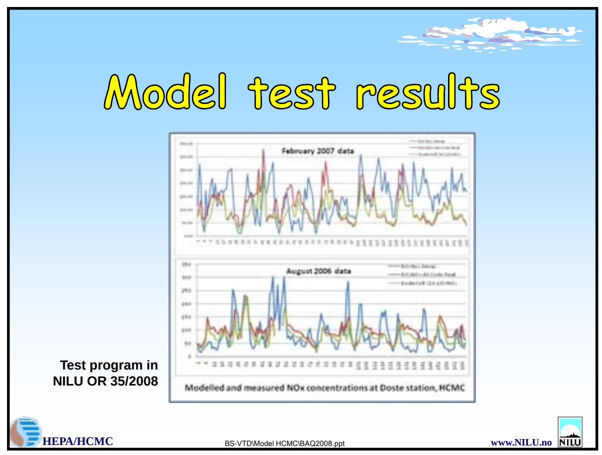
GIS – select grid

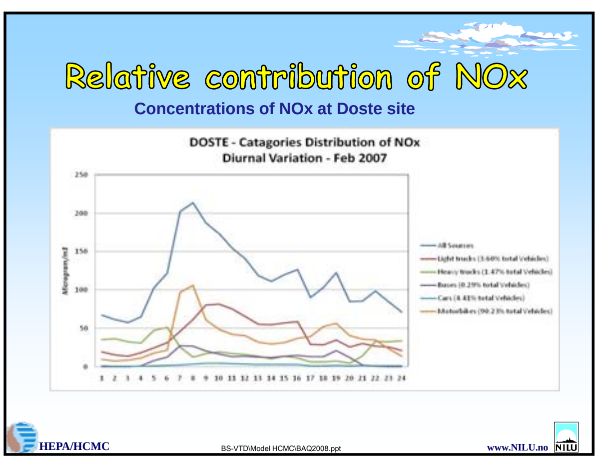


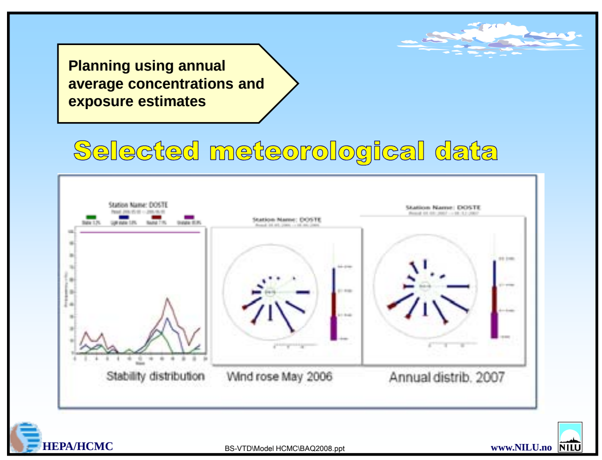

Model test and verification
Emissions
Meteorology
Air Quality
model test
verification
Operational dispersion model
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU


The emission inventory
141 roads
210 stacks
(155 plants and ind.)
all areas
Validity period
2003-2006
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU


First verifications and tests
Meteorological data
Stability at surface
Surf. layer heights
Emission factors
NOx :
30-100 ug/m3
NOx line sources layer 0-50
run 981
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU


Model test results
February 2007 data
August 2006 data
Test program in
NILU OR 35/2008
Modelled and measured NOx concentrations at Doste station, HCMC
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU


Relative contribution of NOx
Concentrations of NOx at Doste site
DOSTE - Catagories Distribution of NOx
Diurnal Variation - Feb 2007
Microgram/m3
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU


Planning using annual
average concentrations and
exposure estimates
Selected meteorological data
Stability distribution
Wind rose May 2006
Annual distrib. 2007
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU

NO_2/NOx ratio

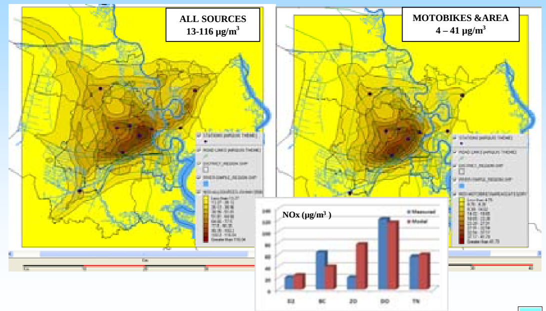
The model estimates NOx
We want to compare to NO_2 limit value for Vietnam

	BC	D2	ZO	DO	TN
NOx	62.8	26.9	32.2	117.0	26.6
NO2	29.4	18.1	17.3	85.3	14.6
NO2/NOx(%)	47	67	54	73	55

NO_2/NOx at urban background station: 0.54.
Evaluate the exceeding of 40 µg/m³ as the annual average NO_2
= the number of people in areas with
NOx concentration above 74 µg/m³

HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

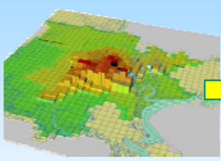
Estimated NOx concentrations, HCMC



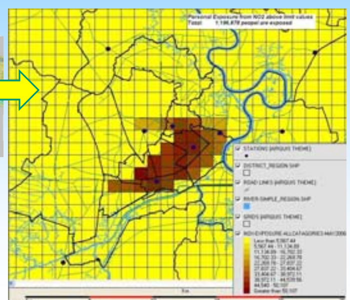
HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

NO_2 exposure – 1,196 mill people

Number of people in areas of NO_2 above limit value for each km²



Population distribution
Concentrations
Exposure



HCMC
2006 scenario

HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

The Government Decision 249/2005/QD-YTTg of October 2005, Vietnam:

"Vietnam motor industry did not have the technology to meet the Euro4 standards"
(Vietnam News Sep 2007)

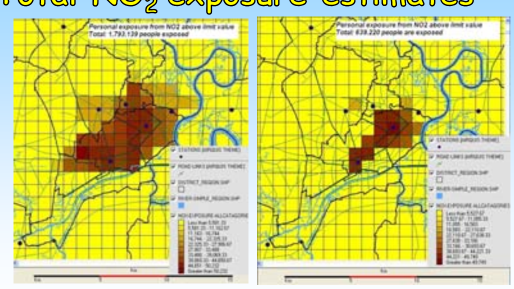
HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

Scenarios for AQ improvement

	Emission factors (EF) NOx					
	pre 2004		2006		Future	
Vehicle class	% distr.	EF (NOx)	% distr.	EF (NOx)	%distrr.	EF (NOx)
Motor cycles (4s)	100	0.3	100	0.23	100	0.23
Pre Cat cars	25	2	10	2	0	2
Gasoline car, US83/87/90	10	0.2	10	0.17	5	0.17
Gasoline car, EURO 1G	20	0.8	20	0.14	5	0.14
Gasoline car, EURO 2G	15	0.3	15	0.09	5	0.09
Gasoline car, EURO 3G	0	0.1	5	0.06	60	0.06
Diesel cars, EURO 1D	20	1	20	0.33	0	0.33
Diesel cars, EURO 2D	5	0.5	5	0.24	5	0.24
Diesel cars, EURO 3D	5	0.5	5	0.15	20	0.15
Light truck, DHLL E1	50	4	50	3.2	30	3.2
Light truck, DHLM, E1	30	5	30	4.185	20	4.1
Light truck, DHLL E2	10	3	10	2.45	30	2.4
Light truck, DHLM, E2	10	5	10	3.171	20	3.1
Heavy trucks, DHLH E1	100	8.5	100	8.12	100	8.1
Buses DHB E1	100	8	100	7.844	100	7.8

HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

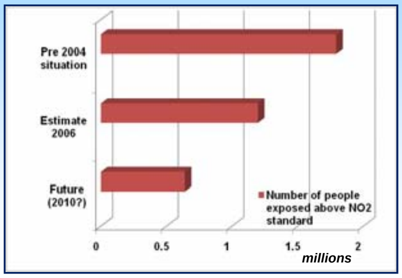
Total NO_2 exposure estimates



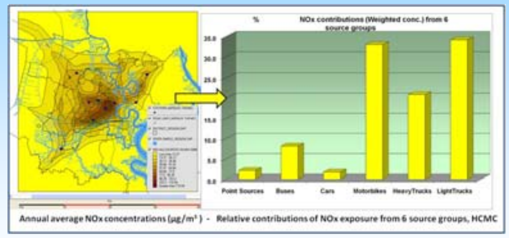
Pre 2004 situation: 1,793.139 persons **Future scenario: 639,220 persons**
Living in areas with NO2 above limit value

HEPA/HCMC BS-VTD\Model HCMC\BAQ2008.ppt www.NILU.no

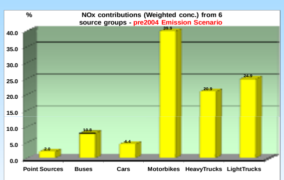
Total exposure 3 scenarios

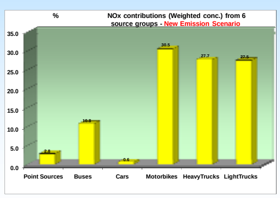


Relative contribution



Change in contribution 2004-2010

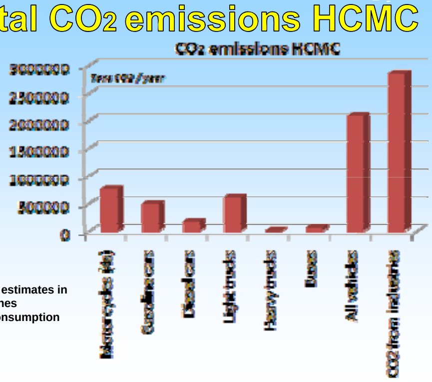




CO_2 emissions from vehicles

Vehicle class	EF CO2	Distance	Vehicles	CO2 emissions
	(g/km)	(km/year)	N	(tons/yr)
Motor cycles (4s)	15	14500	3500000	761250
Gasoline cars	180	18000	150000	486000
Diesel cars	150	18500	60000	166500
Light trucks	220	19700	140000	606760
Heavy trucks	400	20000	300	2400
Buses	360	50000	3200	57600
All vehicles				2080510

Total CO2 emissions HCMC



Industrial CO2
Based on SO2 estimates in 9 industrial zones
and total oil consumption in HCMC 2002

Concluding remarks

A valuable support tool for decision makers !

In spite of uncertainties in some input data;
(emission inventory, e-factors, meteorology) :
The planning tools (models) are able to:

- ✓ Estimate source importance
- ✓ Exposure to the population (future)
- ✓ Relative exposure from traffic
- ✓ Impact of planned actions
- ✓ Estimate greenhouse gas emissions


Thank you !
Questions ???
HEPA/HCMC
BS-VTD\Model HCMC\BAQ2008.ppt
www.NILU.no
NILU