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Screening methods applied for air quality assessment in Dhaka, Bangladesh

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Lecture

SCREENING METHODS APPLIED FOR AIR QUALITY ASSESSMENT IN DHAKA, BANGLADESH

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Abstract:

Air pollution and health have been a major focus in Bangladesh in recent years. In Dhaka, limited air quality monitoring since April 2002 has shown that concentrations of $PM_{2.5}$ and PM_{10} regularly exceeded national and international standards particularly in the non-monsoon period. The local monitoring programme has been spatially limited, however, a more extensive monitoring programme will be fully operating by the end of 2012, which will form the basis for a future air quality management planning.

In the absence of regular and continuous air quality monitoring in Dhaka up to 2012, an overview of the background concentrations and the spatial distribution of air pollution in the Dhaka were needed. In order to obtain this first overview assessment, a variety of screening type techniques have been applied in Dhaka as part of a larger screening programme: passive sampling of gaseous pollutants, grab sampling of PM concentrations, the use of satellite data for Aerosol Optical Depth (AOD) analyses, UV/spectra camera for remote SO2 emission estimates, and simple models for top-down emissions surveys. These screening techniques were performed in Dhaka as a basis for developing a more complete air quality management programme for the Clean Air and Sustainability Environment (CASE) project at the Department of Environment in Bangladesh.

The results of the screening studies within the screening program undertaken so far have shown that PM is the main air pollution problem in Dhaka, where local sources such as brick kilns, traffic (including re-suspension), open air waste burning and small scale industries are the most important sources. However, during the dry season, AOD analyses have also revealed that regional scale pollution (haze) including fine and ultra fine particles may also contribute to the high PM levels in Dhaka. Regional emission databases also confirm estimates of steady increases in PM and gaseous pollutants through 2020. The first tests of using the UV/spectra camera for estimating the flux of pollution coming from single sources, such as brick kilns, have proven successful and has enabled the development of quantification of SO2 emission rates.

While the results of these screening programme in general support previous assumptions and publications in Dhaka, the level of quantification produced from the studies has contributed to a valuable spatial assessment of the current air quality conditions. These rather inexpensive screening studies have provided valuable input to the design of a more advanced monitoring programme as well as input to the development of a complete AQ management programme. The approach used in Dhaka should be considered for producing baseline assessments in other Asian cities. The methods will provide valuable input in the design of more advanced AQ monitoring, emission inventories and models needed for the future AQ management planning system.

Key words: air quality assessment, screening studies

Tag: Ambient Air Quality and Impacts

Introduction

The rapid growth of large cities, especially in the developing countries, has lead to high concentrations of air pollutants at levels that lead to health impacts. These concentration levels are normally unknown to urban planners as well as to the population in general. In order to meet the needs for relevant air quality information, screening studies were planned and performed for Dhaka, Bangladesh.

Dhaka can be considered the megacity with the world's worst urban air quality (Gurjar et al., 2008). The screening studies performed in Dhaka represented a typical approach using simple, inexpensive instruments together with other available techniques. The city of Dhaka is polluted from a combination of numerous local emissions sources as well as sources on a regional and larger scale. This combination of sources and meteorological conditions gives the city exceedingly high air pollution concentrations during the non-monsoon period (November – March). The exposure of the cities estimated 12-15 million residents to this alarmingly poor air quality demands attention including immediate research and corresponding mitigation. It is estimated that if the annual guidelines for PM concentration were met in 2004 that 1,213 premature deaths could have been avoided in Dhaka alone for that year (Aktar, et al., 2005); and the World Health Organization estimates that up to 10,000 premature deaths per year in Bangladesh are attributed to air pollution (WHO, 2009).

In order to provide some initial access to air quality information, a number of screening techniques have been identified and used in the screening program for Dhaka. These screening studies have been designed for different purposes such as:

- Providing a baseline dataset for identifying the level of pollutants in the city,
- Supporting the design of a more permanent air quality monitoring programme,
- Provide input data for the development of an air quality management planning programme.

Screening studies using similar approaches have been applied in Cairo, Egypt (Sivertsen, 2001 a), in Ho Chi Minh City, Vietnam (Sivertsen, 2003), in Dakar, Senegal (Guerreiro, Laupsa and Sivertsen, 2005) in Burgas, Bulgaria (Hak, 2010; Hak and Sivertsen, 2010) as well as in Dhaka, Bangladesh (Randall et.al, 2011).

The screening programme designed and performed in Dhaka have been based on the experience gained from the above mentioned studies, and was part of the BAPMAN project (Randall & Sivertsen, 2011). For these investigations the following techniques and instruments have been applied:

- Passive sampling of gaseous pollutants (NO_2, SO_2, O_3) – February 2011
- Grab sampling of PM concentrations ($PM_{2.5}$, PM_{10}) – February 2011-2012
- The use of satellite data for Aerosol Optical Depth (AOD) analyses and NO2 column estimates, - February 2011
- UV/spectra camera for remote SO_2 emission estimates and plume mapping at brick kilns, - February 2012
- Global and regional databases for top-down emissions surveys. February 2011-2012

The pollutants examined during these studies have included SO_2 and NO_2, as well as O_3 and PM. Results show that the screening studies are able to provide valuable outcomes which include baseline data for inclusion into management planning, as well as showing general spatial distributions of pollutant concentrations.

Designing the screening programme

The screening study programme for Dhaka was undertaken from February 2011 to Febuary 2012. The passive sampling study design was prepared in advance in order to establish the sampling point distributions and identifying the micro environments in which sampling would be undertaken. The components to measure, site selection, including the instrumentation and basic sampling procedures was described and it was decided that 50 NO_2, 50 SO_2, and 20 O_3 samplers would be placed throughout the city.

The newly developed UV/spectra camera was prepared for mapping plumes from selected brick factories. Different model approaches had been tested in order to develop top-down emission estimates for Dhaka. In addition we had prepared traffic counting (vehicle distributions and flows) in order to prepare input data for more advanced models to be used in the future.

Passive sampling site selection

The passive sampling sites were selected based on the following three main criteria:

- Measuring in different microenvironments (e.g. street canyon, road side, urban background, industrial area, regional background areas).
- Selection of compounds to be measured in different microenvironments depending on emission sources.
- Typically sampling along traverses laid out throughout the city perpendicular to the prevailing wind direction

All passive samplers, developed by IVL (IVL,2011) were exposed for a period of 10-12 days.

While an equal spatial disbursement of sites was attempted according to the stated design of different micro-environments, a few sites were targeted for particular reasons:

- Down-wind from the brick kiln fields
- Market areas with high density of people
- Hotel site (15m and 150m above the ground) for temporal variations
- Secure embassy site (urban background site) for 24-hour continuous sampling

PM sampling procedures

PM grab sampling was performed using a TSI DustTrak DRX Aerosol Monitor model 8532 for simultaneous PM10 and PM2.5 fractions during visits to Dhaka between February 2011-2012. Suspended particles were sampled away from direct local sources such as immediate roadside or other areas with direct dust disturbance. Where possible, PM sampling sites were attempted to be placed at existing passive gas sampling sites. A total of 23 unique sites were selected for a one-time sampling of a 30 minute average. At one site, 30 minute samples were collected repeatedly over the whole study period at the same time each day, and at one site we sampled continuously over a 24 hour period. The sampler was calibrated before each sample was taken according to the manufacturers specifications.

The sampler was placed at 1m-2m height above ground and run for 30 minutes. The sampler was left alone for the sampling period, with careful attention to avoid disturbance in the immediate vicinity of the sampler (ie. not to having others walk in the vicinity of the sampler). Data was downloaded from the sampler each evening into a developed MS Excel macro to easily display and analyze the raw data, in addition to calculating the 30 minute average for each PM fraction for each site.

Satellite mapping of PM

It has been shown that in addition to local sources of air pollution, PM levels in Dhaka are to some degree also influenced by contribution from more distant pollution sources through regional and long-range transport. Regional haze on the plains south of the Himalayas due to sources in India burning dirty coal may in periods represent a significant contribution to local PM values in Dhaka.

In order to map this regional scale particulate haze over Bangladesh, satellite data were analyzed for Aerosol Optical Depth (AOD) during February 2011. Tropospheric NO_2 columns between 2002 and 2011 were obtained from the SCIAMACHY (SCanning Imaging Absorption spectro Meter for Atmospheric CartograpHY) sensor onboard of Envisat (Bovensmann et al., 1999).

UV/spectra camera

A new ultra-violet imaging camera has been developed and adapted at NILU for the purpose of quantifying and detecting industrial and natural emissions of gases and particles (Bluth et al., 2007). The system is calibrated using standard gas cells and has been used to measure SO_2 from a volcanic source and also from industrial stacks. The portability and low cost of the system make it attractive for use at industrial plants and for measuring fugitive emissions. Because the camera can sample rapidly (several images per second), features in the images can be tracked and the “in plume" wind speed and gas flux can be derived. This camera was deployed in Dhaka during February 2012.

Top-down emissions estimated from databases

In a developing country such as Bangladesh there is a lack of available compiled data on air emissions. Two different approached have been applied in order to get some first-hand information about the emission sources in Dhaka.

The model system GAINS (IIASA, 2008) can be used for “screening-type study” tool for emissions estimates and future trends. The GAINS approach is a simplified generalization tool to be used to pin point pollutants and related sources which deem closer research and analysis using more specific tools or ground-based monitoring. In addition, other databases have been utilized such as Emissions Database for Global Atmospheric Research (EDGAR) and Regional Emission Inventory in Asia (REAS). Data was compiled from these databases from February 2011-2012.

Results and Discussion

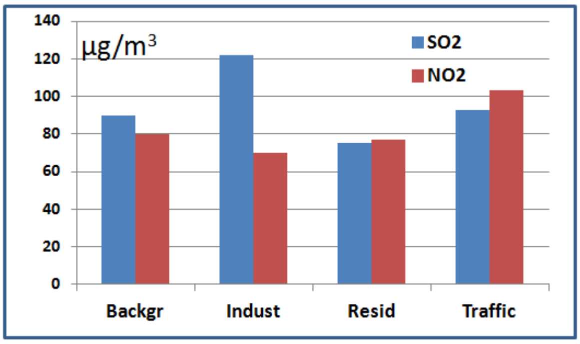
It can be concluded from these screening results that Dhaka experiences severe air quality problems in the winter season, and the sheer volume of human exposure to these ambient pollutants is staggering. It is encouraging that the CASE project is currently improving air quality management for the country, and that the BAPMAN project (BAPMAN, 2010) is increasing capacity building where necessary, and that the BAPS project is generating additional data as necessary.

The screening study that has been performed for Dhaka represented a first glance at the level of pollutants, and an indication of pollution distribution and possible hot spots. It should again be noted that because this data was collected during the dry winter season, the results are most likely representing the highest/maximum pollution concentrations.

Concentrations of gaseous pollutants

Through passive sampling the average concentration values of SO_2 measured at 48 unique sites during February 2012, ranged from 38 to 199 µg/m^3, with an average concentration of 87 µg/m3 for all sites. In relation to the Bangladeshi air quality standards (DOE, 2005) for SO_2 concentrations, it is likely that none of the sites exceeded the standard of 365 µg/m3 SO_2 over a 24-hour period. However, all of the sites may have exceeded the WHO AQG of 20 µg/m3 SO_2 over a 24-hour period, and at least 7 sites exceeded the EU limit value of 125 µg/m3 SO2 over a 24-hour period.

Of the 47 NO_2 samplers placed at 47 unique sites, the NO_2 average concentration values ranged from 36 µg/m3 to 161 µg/m^3 , with an average concentration of 83.6 µg/m^3.

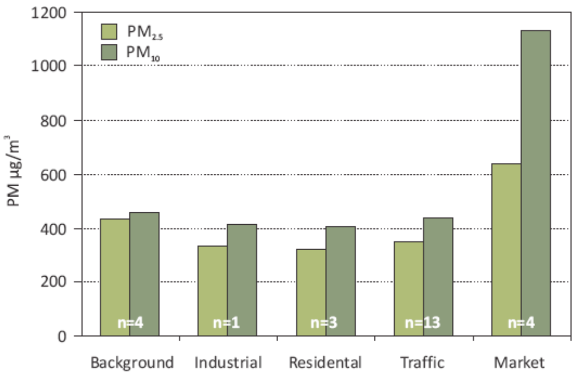


The highest average SO2 concentrations were found at industrial sites, with an average for the 12 days of 122 µg/m^3. The highest average NO2 concentration was measured at traffic sites with an average of 102 µg/m^3.

The average ozone concentrations measured over the 12 day period typically ranged between 30 and 60 µg/m3, which is similar to what we have found in other large cities in Asia. The highest concentrations were found at background sites. In order to evaluate possible exceeding of standards, ozone will have to be measured with a one-hour resolution.

Very high PM concentrations

Short term concentrations of PM_{10} and $PM_{2.5}$ were higher in Dhaka than NILU has seen in cities we have compared to. It is also clear that the concentrations of PM frequently exceeded national and international limit values (especially during the winter months). Local sources to these values include the numerous brick kiln fields, motorized diesel vehicles, open-air waste burning and re-suspension of dust.



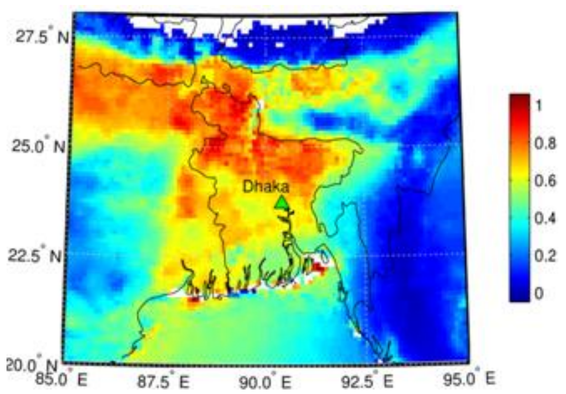
Average PM_{10} and $PM_{2,5}$ concentrations as measured in four different micro environments; background, industrial, residential, traffic and at a busy marked. At the highly polluted marked about 50% of the PM was PM_{10}.

Of the 23 PM_{10} grab samples collected during the February 2011 campaign as 30-minute averages, concentration values ranged from 258 µg/m^{3}to 2039 µg/m^3, with an average concentration of 613 µg/m^{3}for all sites. The average $PM_{2.5}$ concentration from the 23 grab samples taken was 439 µg/m^{3}for all sites. The ratio of $PM_{2.5}$ to PM_{10} was on the average 71 %, which is higher than we have found in other cities. This might be due to a fairly large fraction of small regional haze particles.

Continuous sampling of $PM_{2,5}$ and PM_{10} undertaken during 24-hours at one of the residential sites gave average PM_{10} concentration of 413 µg/m3, and for $PM_{2,5}$ 381 µg/m^3. Concentrations ranged between 200 and 900 µg/m^3. The highest concentrations were recorded during the first morning and daytime hours when visible amount of smog was seen over Dhaka. During the lower concentration period the air was visibly much clearer.

Satellite mapping

The AOD data analyzed from satellite images gave a regional-scale spatial overview of PM levels in the Bangladesh area during the February 2011 campaign. We also wanted to investigate to what extent the AOD data can duplicate time series measured on the ground as part of the screening study

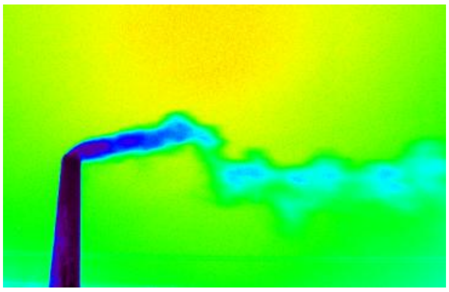


The overall mean AOD over Bangladesh for the study period is shown in the Figure. The highest AOD and thus PM load is found in a zonal band along the south side of the Himalaya with a southward extension over Bangladesh. Over Bangladesh a north-south gradient is visible, with Dhaka showing mean AOD values of around 0.6. These maps were created for everyday during the measuring period.

MODIS AOD values (NASA/Gsec, 2011) were compared with daily 30 min average PM measurements performed at one of the urban sites during the study period. The AOD data shows a remarkably good temporal agreement with the PM measurements.

UV/spectra camera plume mapping

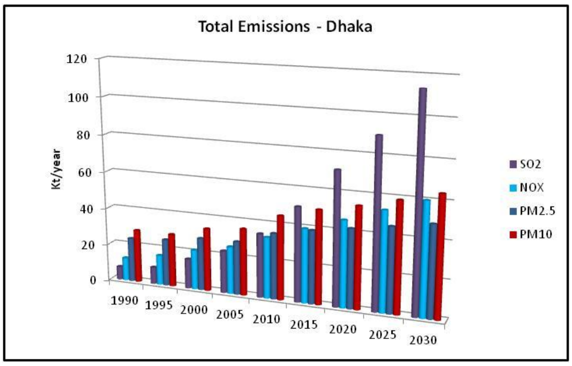
The first sampling with the UV camera was valuable related to understanding the SO_2 emission intensities during various stages of the brick kiln process. It also gave greater insight into the plume dynamics of brick kilns and SO_2 concentrations within.

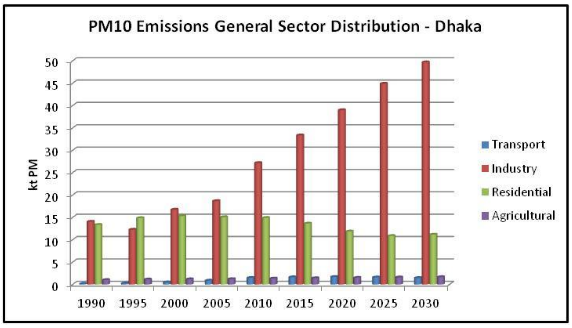


The method has proven valuable for estimating SO2 fluxes and from that generating future estimates of emission rates of SO_2. The results from measurements at brick factories in Dhaka are still under evaluation. There is no doubt, however, that the method will be valuable in the future in order to measure emission rates from different industries.

Estimating top-down emission rates

The total top-down emissions for PM, SO_2, NO_X, and GHGs for 2010, as well as the decadal trends, have been investigated for Dhaka. The top sectors, sub-sectors, and activities making up the emissions for each pollutant have also been analyzed. Emissions of all criteria pollutants are projected to increase through year 2030, with a much sharper increase for SO_2.



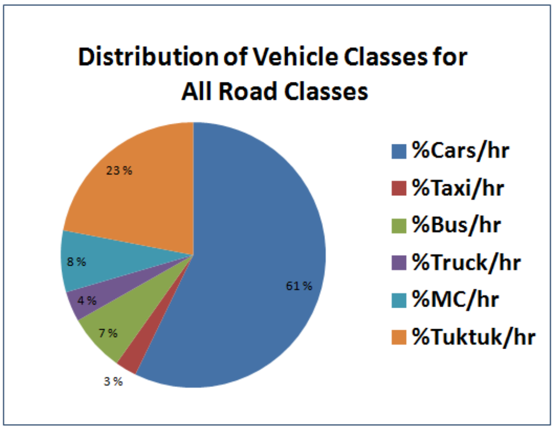


Estimates of PM10 emissions indicate a steady increase since 1990, where 2020 estimations are projected to be double 1990 values, with a sharp increase from the industrial sector and decreases from the residential sector.

Initially it was thought that GAINS was producing a major underestimation of PM emissions for the transportation sector, as first stated in Sivertsen (2010). After field visits to Dhaka as well as through additional research, it was discovered that up to 73% of the traffic sources (not counting motor bikes) runs on CNG (Wadud, 2011), which would explain the low PM estimations from GAINS for this sector.

Traffic flows

The traffic counting (screening) design was fairly simple but will still give some basic information important for future modeling of traffic flows in Dhaka. During traffic sampling from February 2011-2012, it was found that the greatest flow rates were found for cars running on primary roads, followed by auto-rickshaws (baby taxis) on primary roads. Motorcycles and buses represented both about 10% of the total flow rates, while trucks and taxis make up less than 5% of the total flow rates. The average total traffic volume and vehicle distributions are as expected. An approximate 60:20:20 ratio for cars: auto-rickshaw: other vehicles are most likely a good average ratio to depend upon. It should also be noted that some locations are dominated solely by human-powered rickshaws.



Conclusion and Summary

Simple and inexpensive screenings studies as those performed in Dhaka have contributed to a valuable spatial assessment of the current air quality conditions. They have provided valuable input to the design of a more advanced monitoring programme as well as input to the development of a complete AQ management programme.

There are limitations related to the methods compared to more advanced, more expensive and continuous monitoring of air pollution. The passive sampling of gaseous pollution only gives an integrated concentration (average over 2 weeks). The PM grab samples are taken over 30 min periods, but include one second resolution in the basic data. Traffic counting during the screening study only gave one hour average traffic flows. In addition, the top-down emission estimates can never be as precise as bottom-up methods.

The screening studies represent cost efficient and fast methods for obtaining a first glance at the air pollution problem in a given urban area. Some conclusions are:

- The results give a good overview of the AQ status of Dhaka and responsible sources
- We have seen very high PM concentrations during the dry season due to combined local and regional problems
- The SO_2 seem to come from industries, while the highest NO_2 measured are close to major roads, with low PM emissions from passenger vehicles due to CNG fuels, but possibly high re-suspension values.
- The first use of satellite data have proven valuable both for PM assessment and emission inventories
- Regional emission databases have given the indication of increased emission into the future, and the possible sectors and specific sources for the increase
- We have collected some traffic flow data, which may prove important in the emission inventories for modelling

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Screening methods applied for AQ assessment

in Dhaka, Bangladesh

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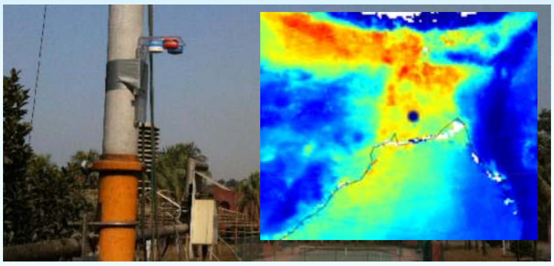

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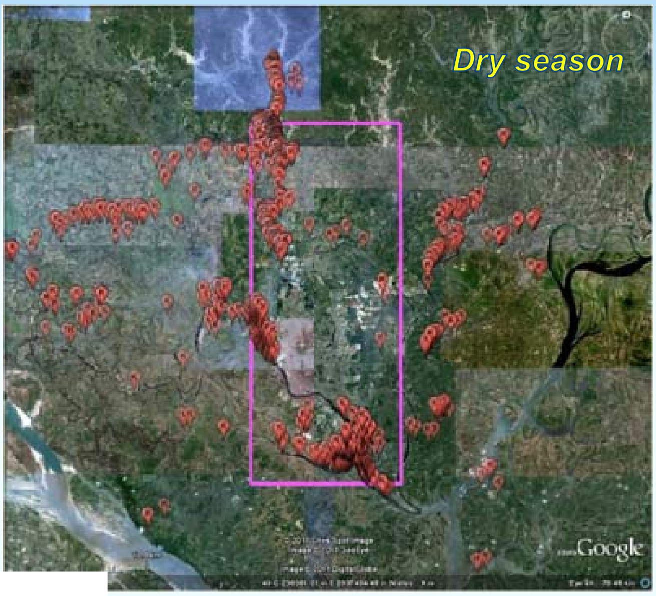
Dhaka Sources



Main Sources:
Brick kilns,
Local burning,
Re-suspension on roads,
Local industry
Regional influx.
Vehicles (CNG)
Power Plants
Large Industries
Residential

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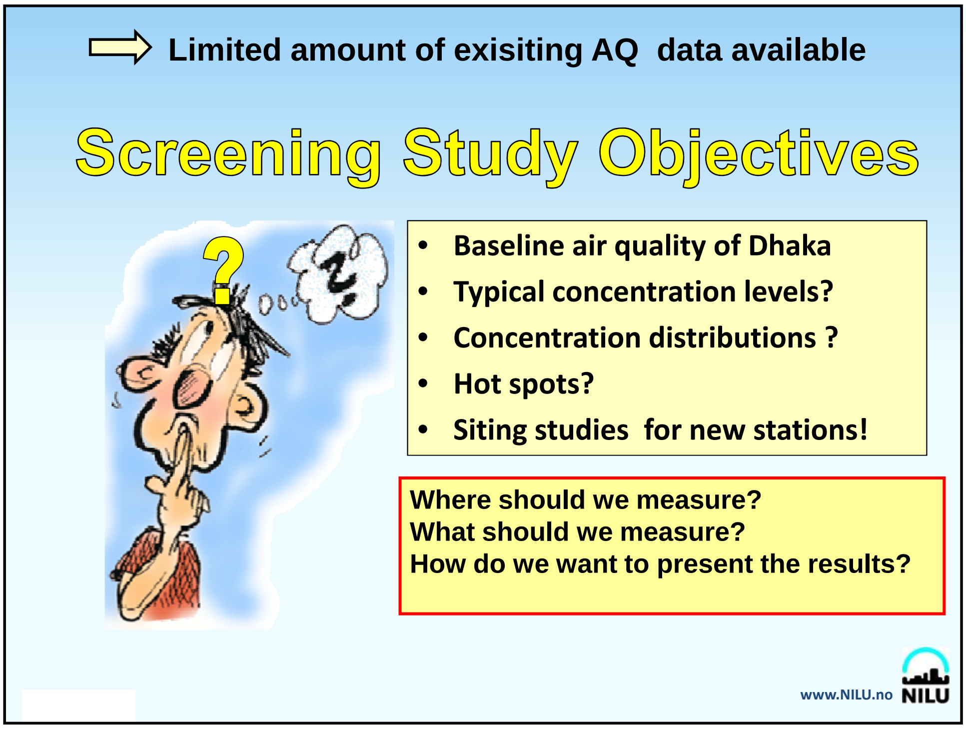
Limited amount of exisiting AQ data available
Screening Study Objectives
• Baseline air quality of Dhaka
• Typical concentration levels?
• Concentration distributions ?
• Hot spots?
• Siting studies for new stations!
Where should we measure?
What should we measure?
How do we want to present the results?
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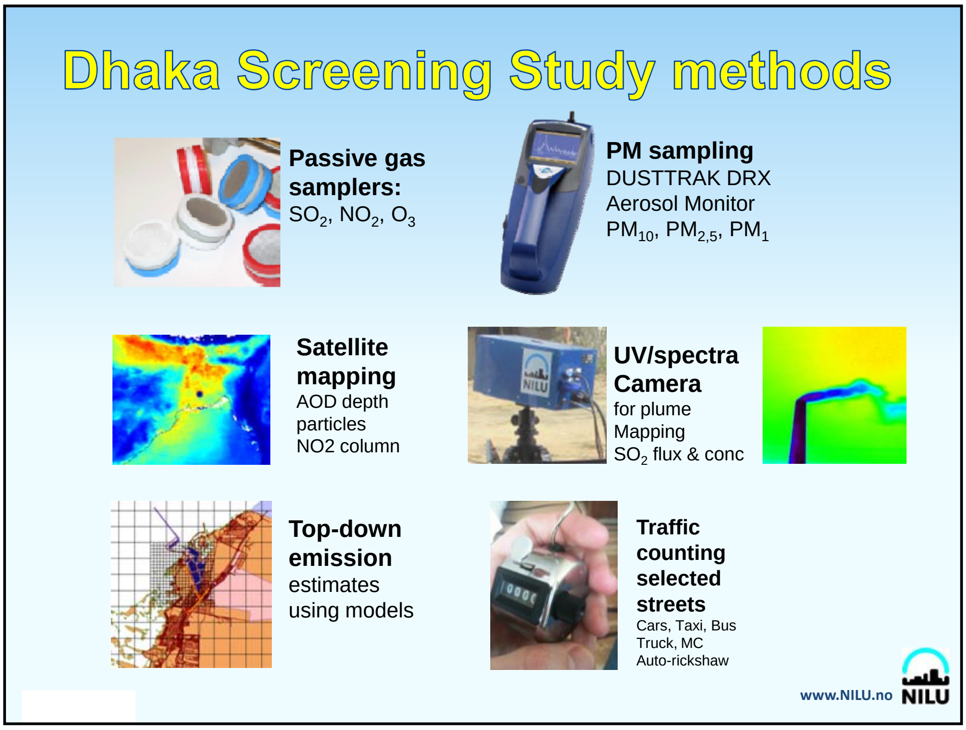
Dhaka Screening Study methods
Passive gas samplers:
SO_2, NO_2, O_3
PM sampling
DUSTTRAK DRX
Aerosol Monitor
PM_{10}, $PM_{2,5}$, PM_1
Satellite mapping
AOD depth
particles
NO2 column
UV/spectra Camera
for plume
Mapping
SO_2 flux & conc
Top-down emission
estimates
using models
Traffic counting selected streets
Cars, Taxi, Bus
Truck, MC
Auto-rickshaw
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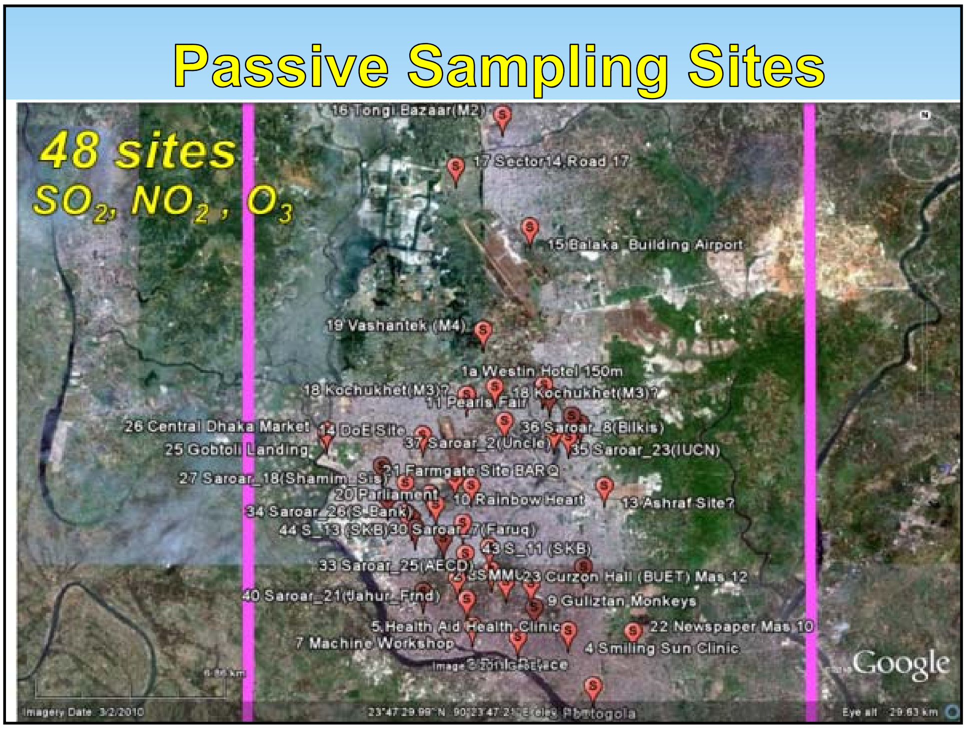
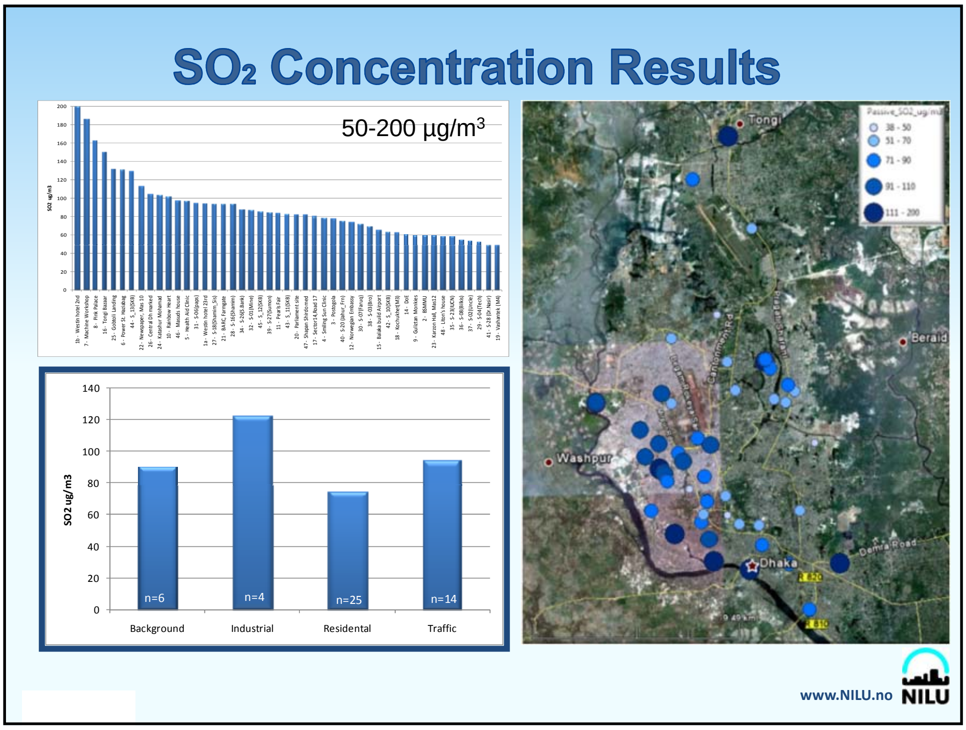

Passive Sampling Sites
48 sites
SO2, NO2, O3
16 Tongi Bazaar(M2)
17 Sector14,Road 17
15 Balaka Building Airport
19 Vashantek (M4)
1a Westin Hotel 150m
18 Kochukhet(M3)?
11 Pearls Fair
18 Kochukhet(M3)?
26 Central Dhaka Market
14 DoE Site
36 Saroar_8(Bilkis)
25 Gobtoli Landing
37 Saroar_2(Uncle)
35 Saroar_23(IUCN)
27 Saroar_18(Shamim_Sis)
21 Farmgate Site BARQ
20 Parliament
10 Rainbow Heart
13 Ashraf Site?
34 Saroar_26(S Bank)
44 S_13 (SKB)
30 Saroar_7(Faruq)
43 S_11 (SKB)
33 Saroar_25(AECD)
23 Curzon Hall (BUET) Mas 12
40 Saroar_21(Jahur_Frnd)
9 Gulitzan Monkeys
5 Health Aid Health Clinic
22 Newspaper Mas 10
7 Machine Workshop
4 Smiling Sun Clinic
Google
Imagery Date 3/2/2010
Eye alt 29.63 km


SO2 Concentration Results
50-200 µg/m3
SO2 ug/m3
140
120
100
80
60
40
20
0
n=6
n=4
n=25
n=14
Background
Industrial
Residental
Traffic
Tongi
Washpur
Dhaka
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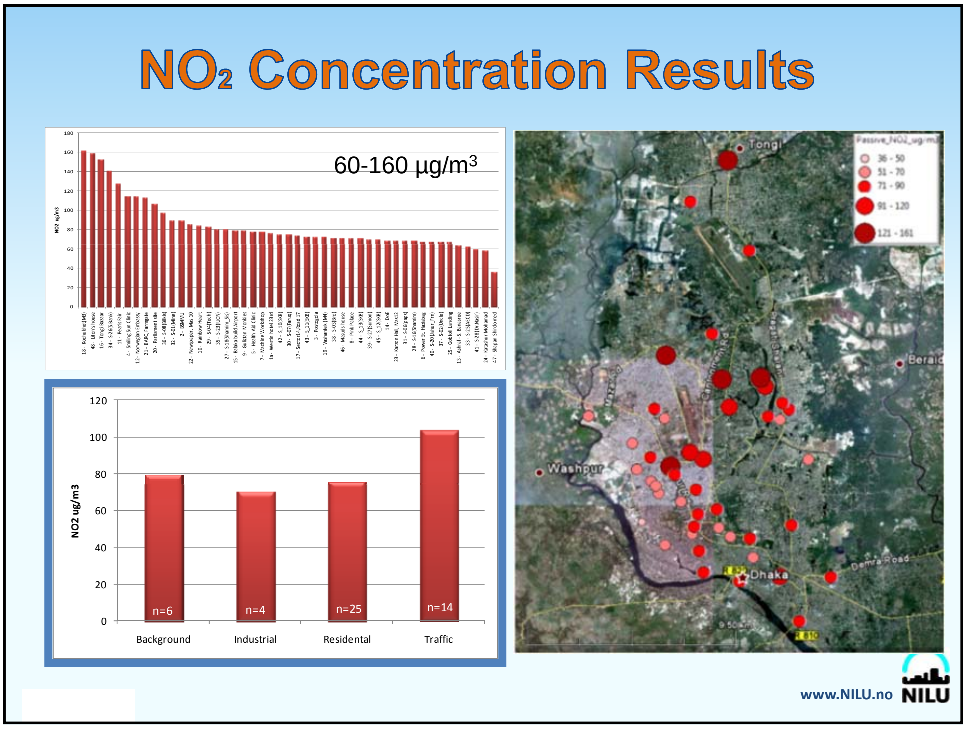
NO2 Concentration Results
60-160 µg/m3
NO2 ug/m3
n=6
n=4
n=25
n=14
Background
Industrial
Residental
Traffic
Tongi
Washpur
Dhaka
Beraid
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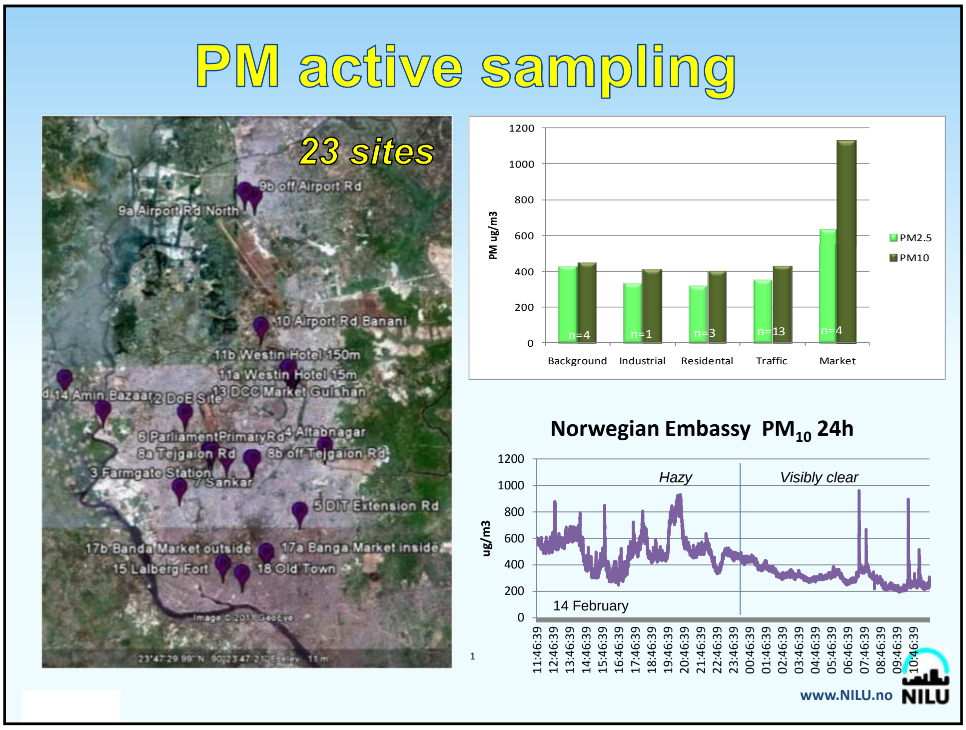
PM active sampling
23 sites
9b off Airport Rd
9a Airport Rd North
10 Airport Rd Banani
11b Westin Hotel 150m
11a Westin Hotel 15m
14 Amin Bazaar
2 DoE Site
13 DCC Market Gulshan
6 ParliamentPrimaryRd
4 Altabnagar
8a Tejgaion Rd
8b off Tejgaion Rd
3 Farmgate Station
7 Sankar
5 DIT Extension Rd
17b Banda Market outside
17a Banga Market inside
15 Lalberg Fort
18 Old Town
PM ug/m3
PM2.5
PM10
n=4
n=1
n=3
n=13
n=4
Background
Industrial
Residental
Traffic
Market
Norwegian Embassy PM10 24h
ug/m3
Hazy
Visibly clear
14 February
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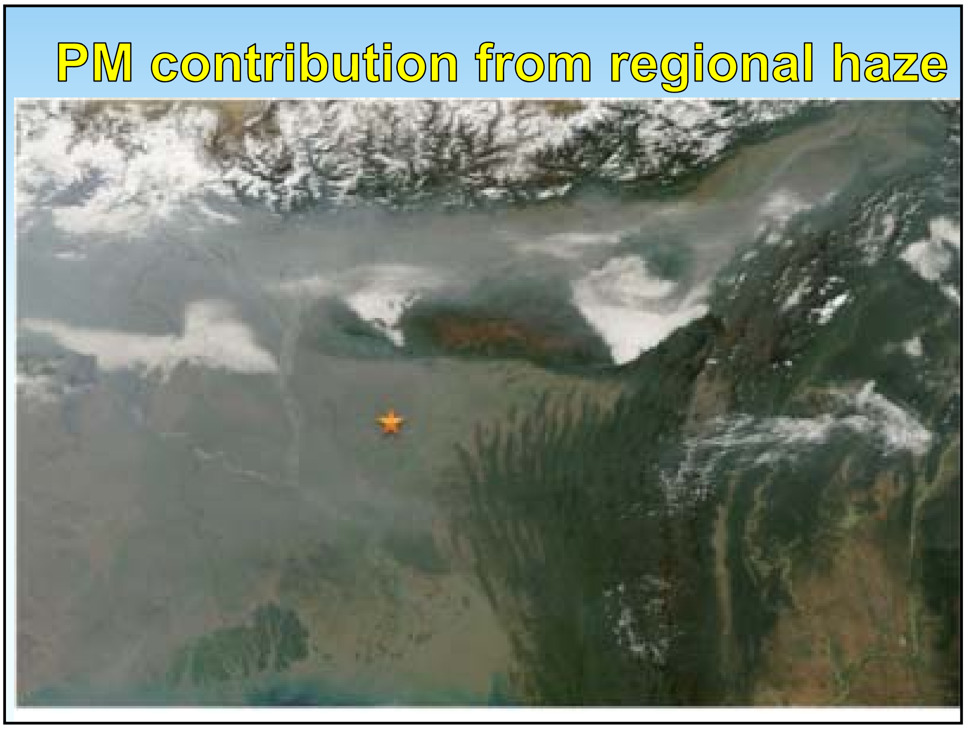
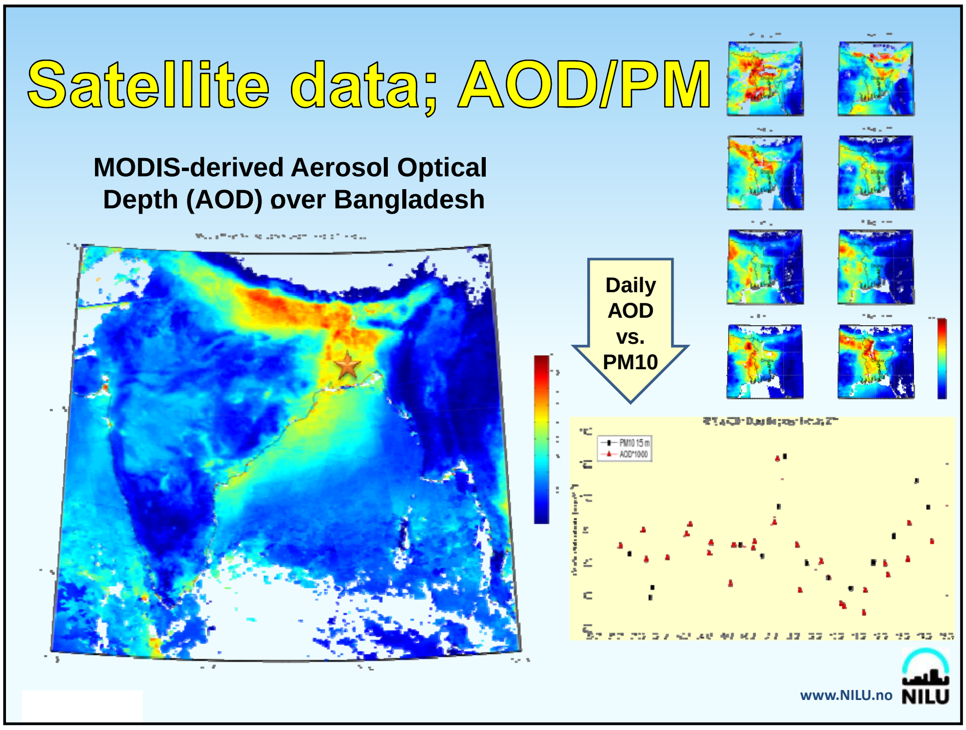

PM contribution from regional haze


Satellite data; AOD/PM
MODIS-derived Aerosol Optical Depth (AOD) over Bangladesh
Daily AOD vs. PM10
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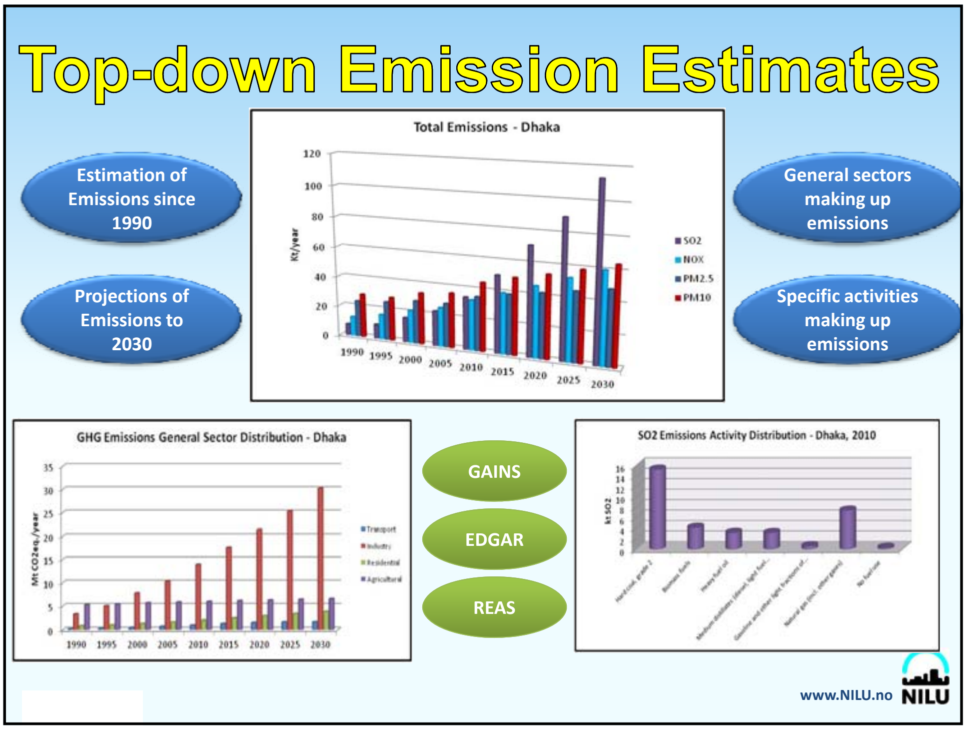
UV/spectra Camera
Plume mapping
SO2 flux & concentrations


Top-down Emission Estimates
Estimation of Emissions since 1990
Projections of Emissions to 2030
Total Emissions - Dhaka
Kt/year
SO2
NOX
PM2.5
PM10
1990 1995 2000 2005 2010 2015 2020 2025 2030
General sectors making up emissions
Specific activities making up emissions
GHG Emissions General Sector Distribution - Dhaka
Mt CO2eq./year
GAINS
EDGAR
REAS
SO2 Emissions Activity Distribution - Dhaka, 2010
kt SO2
www.NILU.no
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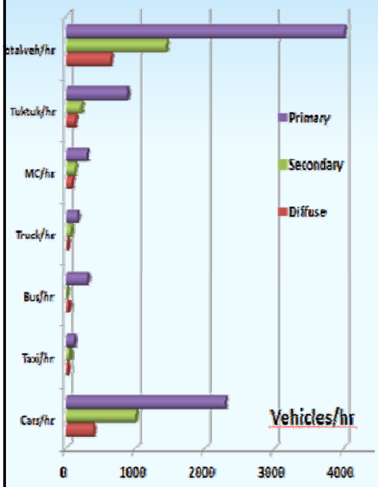
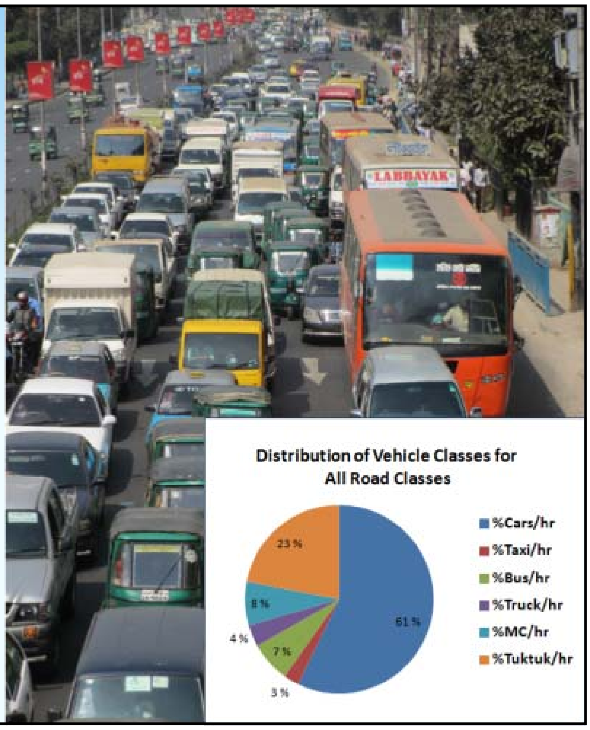
Traffic countings





Conclusions and comments

Some main outcome of the screening study:

- ✓ First comprehensive AQ data in Dhaka for some time
- ✓ Gave a good overview of the AQ status of Dhaka
- ✓ Input for local DoE to collect, analyze, and report on data
- ✓ Excellent input to further AQ Management in Dhaka
- ✓ Very high PM concentrations during dry season
- ✓ SO2 from industry, NO2 from traffic
- ✓ First indication of traffic flow densities
- ✓ Valuable use of satellite data for AQ and for emissions

Limitations:

Passive Sampling gives average concentration over 2 weeks
PM grab samples only give 30-minute average
Traffic counting only 1-hour averages

Next: Continuous monitoring and detailed 24-hour traffic surveys!

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Thank you !
Questions ???
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