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Dhaka, Bangladesh

Norwegian Institute for
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NILU

Air Quality Management Project,
Dhaka, Bangladesh, 2006

Final report, Mission 1
16 – 27 January 2006

Bjarne Sivertsen and Herdis Laupsa

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Table of contents

List of Abbreviations

ADACS	Automatic Data Acquisition System
AirMetrics	MiniVol Portable Ambient Air Sampler
AQI	Air Quality Index
AQMP	Air Quality Monitoring Programme
BEMP	Bangladesh Environmental Management Project
CAMS	Continuous Air Monitoring Station
CIDA	Canadian International Development Agency
CO	Carbon monoxide
DoE	Department of Environment
DTAC	Departmental Technical Advisory Committee
EIA	Environment Impact Assessment
EI	Emission inventory
GIS	Geographical Information System
GoB	Government of the People's Republic of Bangladesh
ISO	International Organization for Standardization
NEMAP	The National Environmental Management Action Plan
NILU	Norwegian Institute for Air Research
NO_2	Nitrogen dioxide
NORAD	Norwegian Agency for Development Cooperation
MoE	Ministry of Environment
PM_{10}	Particulate matter with diameter Less than 10 micrometer
$PM_{2,5}$	Particulate matter with diameter Less than 2,5 micrometer
QA	Quality Assurance
QC	Quality Control
SMEC	SMEC International Pty Ltd.
SO_2	Sulphur dioxide
SOP	Standard Operating Procedures
TA	Technical Assistance
TOR	Terms of Reference

1 Introduction

NILU experts have been requested to review the Continuous Air Quality Monitoring Programme under the Air Quality Monitoring Project (AQMP) in Dhaka. Measurements have been going on for about four years and the performance of the system as well as the utilization of the data generated have to studied and evaluated.

Two experts were appointed to complete all activities as mentioned in the Terms of Reference (ToR) of AQMP in the People's Republic of Bangladesh. The Sub Committee of DTAC (Departmental Technical Advisory Committee) of AQMP has selected the following two experts from NILU as per CVs:

1. 1 Bjarne Sivertsen
2. Larssen Steinar

Mr. Bjarne Sivertsen was supported by Mrs. Herdis Laupsa in January 2006 and Mr. Steinar Larssen will bring an expert on instruments and QA/QC procedures; Mr. Leif Marsteen, when he visits Dhaka in March 2006.

This report contains the main findings from the studies undertaken during Mission 1 undertaken from 16 to 27 January 2006 in Dhaka.

1.1 Objectives

The main objective of Mission 1 of the project was to review the existing AQM activities in Dhaka, Bangladesh as well as assist in the development of criteria for site selection, development of databases for air quality and meteorological data, updating the training plan, introduce methods for the development of an emission inventory and assist the AQMP staff in the use of dispersion models.

1.2 Scope of work

The work was based on the ongoing projects in Dhaka, and the international consultant on AQM provided support and assessment of the tasks mentioned in the objectives. Local experts supported the international team throughout the evaluation, discussions

and various meetings in Dhaka. The international team provided extended technical input to the AQMP staff according to the specifications given in the project plan based on the Terms of Reference.

Mr Bjarne Sivertsen and Mrs Herdis Laupsa went through the whole AQM programme, collected information and data and prepared a short seminar to introduce the AQMP team to an air quality management systems available internationally. They discussed site selection criteria, performed database assessment, training and assisted the design of small studies for brick kilns.

At the end of the Mission the experts introduced the AQMP team to emission inventory systems, and also provided DoE with templates for starting collecting emission data from the most important sources in Dhaka.

Selected experts appointed by the AQMP team were introduced to a simple model (CONCX) for assessment of emissions from point sources. Some training in the use of this model was provided and the model was installed at the DoE.

Some discussions were started concerning the use of data for air quality assessment, but this task will also be continued during Mission 2.

2 The review project

2.1 The evaluation team

The evaluation team for the Air Quality Monitoring Programme (AQMP) in Dhaka comprised two independent Missions to Dhaka using two international consultants, both having extensive practical experience of air quality monitoring, assessment and management projects in the SE Asia Region and world-wide. The two consultants were:

- Bjarne Sivertsen, Associate Research Director- NILU, Norway
- Steinar Larssen, Associate Research Director- NILU, Norway

The two consultants were supported by two experts from NILU, covering emissions and modelling and QA/QC systems. These two were

- Herdis Laupsa, senior scientist, NILU Norway
- Leif Marsteen, director for instrument and monitoring at NILU Norway

2.2 General approach

Our overall assessment of the Air Quality Monitoring Programme in Dhaka was undertaken through a two-week visit to Dhaka (Mission 1), undertaken from 16 to 27 January 2006. Its main purposes were to meet a range of project participants and to gather information about the ongoing activities at AQMP.

An Inception report have been developed and presented during the first days of the field investigations (Sivertsen and Laupsa, 2006a). Much of this final report has been based on the preliminary findings reported in the Inception report.

In addition to a number of meetings with AQMP personnel, we also met personnel from Atomic Energy Institute, the World Bank and the Norwegian Embassy.

The presently operated monitoring and AQM systems, tools and technologies were introduced and discussed during the visits with working level as well as senior/management personnel.

The AQMP project design, reports and deliverables were collected and read.

The AQMP project technologies, hardware and software, focussing on WinCollect and its various functionalities were also studied, discussed and evaluated. We also reviewed as far as possible the Air Quality Management systems in routine operation The expert team assessed current priorities and further AQM needs in Dhaka, together with specific requirements from the staff at AQMP.

Based on the scope of work described in the ToR the work performed during Mission 1 was divided into 7 tasks:

- Task 1, Monitoring sites and site selection
- Task 2, Database for air quality and meteorological data
- Task 3, Data management, analysis and report preparation
- Task 4, Terms of references for small and medium enterprises
- Task 5, Updating the training plan for AQMP/DoE staff
- Task 6, Emission inventory (EI) database for Dhaka city
- Task 7, Dispersion Modelling for Dhaka

The work performed in these tasks is presented in the following chapters. Findings, conclusions and further work necessary to bring the AQMP project and staff forward to enable air quality assessment, management and planning has been indicated after discussions with the DoE team.

The people met during the Mission are presented in Appendix A.
The schedule for Mission 1 has been presented in Appendix B.

3 Task 1: Monitoring sites and site selection

3.1 Objective

The objectives of this task are to assist in the development of criteria for **site selection** to get representative spatial data for citywide air pollution and develop a monitoring plan for Dhaka using mobile samplers.

The task includes:

- Background for siting of monitoring stations
- Visit to the sites, discuss representativity
- Evaluate sites, compounds and meteorological data
- QA/QC procedures (calibration, manuals and SOP)

A memo was prepared for the discussions prior to the meetings as presented in the Inception report Appendix C. Some of the criteria presented in the memo as well as the siting criteria used for the further recommendations were developed as part of guidance for the European Directives (EU 2001).

3.2 The monitoring and reporting system in Dhaka

The Air Quality Management Project (AQMP) operates the air quality monitoring in Dhaka through the Continuous Air Monitoring Station (CAMS) since April 2002 and by simple PM_{10} and $PM_{2,5}$ samplers based on the MiniVol Portable Ambient Air Sampler "AirMetrics". A more detailed presentation of the present system is given in the Inception report. The results of the monitoring have shown that $PM_{2.5}$ and PM_{10} concentrations represent the major problem in Dhaka.

3.2.1 Stations in Dhaka and parameters measured

The following measurement sites are being operated in Dhaka as of January 2006:

Sangsad Bhaban (Continuous Air Monitoring Station, CAMS). It is situated in an open, flat area approximately 200-300 meters from two moderately trafficked roads,

Manik Mia Avenue to the south of CAMS and Rokeya Sharani Road to the east. There are no significant sources of air pollution such as construction sites or industrial premises in the immediate vicinity of CAMS. There are no buildings present around the CAMS. However, the nearest trees are located approximately 10 meters from the CAMS sampling points.

The CAMS station at Sangsad Bhaban, is measuring air pollutants and meteorological parameters.
The pollutants that are monitored at CAMS since April 2002 are as follows:

1. Particulate Matter (PM_{10} and $PM_{2.5}$)
2. Carbon monoxide (CO)
3. Oxides of Nitrogen (NO_2 and NO)
4. Sulphur Dioxide (SO_2)
5. Ozone (O_3)

The meteorological parameters are horizontal and vertical wind speed, horizontal wind direction, ambient temperature, relative humidity, solar radiation and rainfall.

The location of the measurement stations in Dhaka is presented in Figure 1.

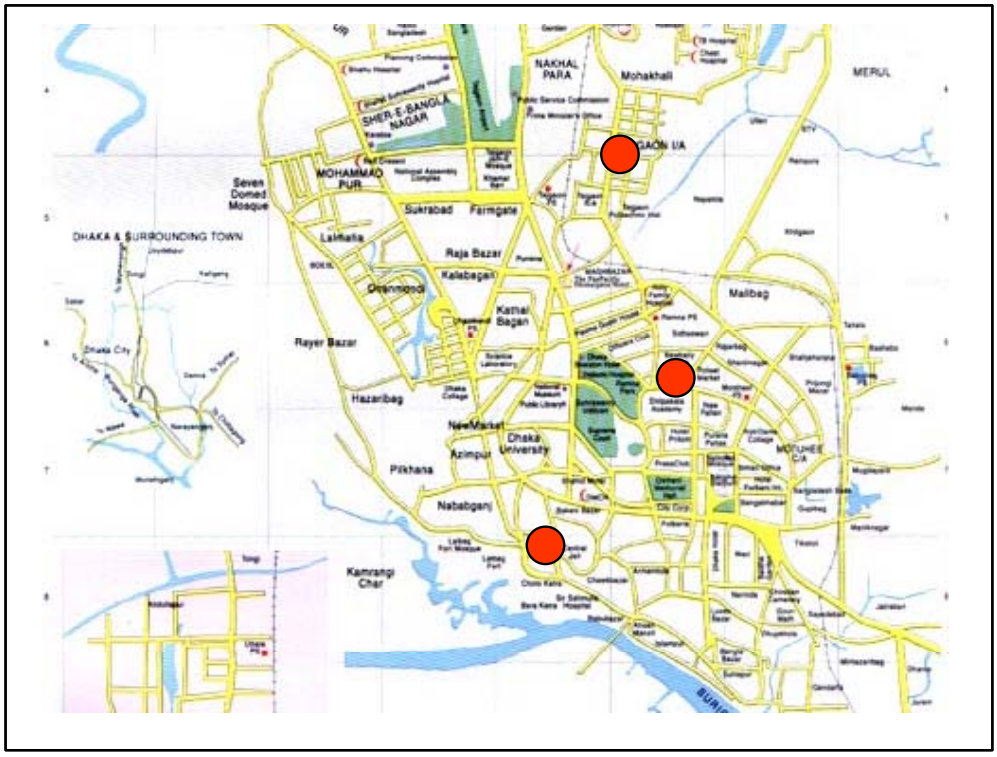


Figure 1: Location of some of the monitoring stations in Dhaka.

The PM instruments and the air intake for the gas monitors are on the roof of a building (approximately 5 m above ground level). The meteorological mast (7 m) is also located

on the roof. The wind speed (horizontal and vertical) and the wind direction are measured in the top of the mast (approximately 10-12 m above ground level).

Figure 2: Instruments at the CAMS station at Sangsad Bhaban.

Tejgaon (**Bitac**) station is located in a small industrial area of Dhaka. The instrument, a MiniVol Portable Ambient Air Sampler; AirMetrics, is located on a top of a building approximately 5 m above ground level with intake only 40 cm above the roof surface. The AirMetric is located directly on the roof and not using a stand. The station is surrounded by small industries such as workshops and small enterprises.

Rajarbag station is located in the old town of Dhaka within the area of the police department of Dhaka. The AirMetrics instrument is located on a top of a shed approximately 3-4 m above ground level. The instrument is located directly on the roof with the intake only 40 cm above the roof surface.

Lalbag is a planned location for a future permanent urban monitoring background station, downwind of the Dhaka city area. Two different locations were suggested. One on a roof of a building close to the Lalbag fort, the second suggested location was on a balcony of the Lalbag fort museum. Both sites are good urban background station downwind the city. We suggested that measurements could start immediately at the roof of the building outside the fort premises.

3.2.2 Instruments and monitoring status

Most of the instruments have been delivered by Ecotech Australia. Thermo Environment has more recently delivered many of the PM samplers used at the CAMS station.

A data retrieval system, WinCollect, was delivered for retrieval of data from the automatic gas samplers and meteorological data. This system does presently not work properly. An overview of the available instruments with a status description as of 18 January 2006 was presented in the Inception report.

There have been several problems with the gaseous pollutant monitoring system. This was also reported by SMEC in 2003 (SMEC, 2003). Instrument malfunctions combined with limited possibilities for maintenance and repair have been among the reasons. The total QA/QC procedures have also been questioned as discussed in Chapter 3.3.4.

3.2.3 The sites selected by AQMP

The sites selected for measurements of gaseous and particulate matter are mainly to be considered urban background stations. At the CAMS the PM instruments are located on a top of a low building. The air intake for the gas components is located only about 40 cm above the roof surface.

For gaseous pollutants only one site has been selected. For PM a total of six sites have been identified. During our Mission measurements were being undertaken at 3 of these sites. The expert team visited 4 of these sites. The meteorological station at CAMS measuring the wind speed (horizontal and vertical) and the wind direction in the top of the mast is placed approximately 10-15 m above ground level. The station is located in an open area and seems representative for the general airflow of the city of Dhaka.

The sites selected for PM_{10} and $PM_{2,5}$ sampling using; AirMetrics, are mostly located on roof tops more than 50 m away from major roads.

3.2.4 Quality assurance and quality control

A Quality Control and Quality Assurance (QA/QC) programme has been prepared for AQMP. Some of the program has been implemented at CAMS. As mentioned by SMEC there are still lots of works remaining to meet the requirements of a good QA/QC programme.

As air monitoring is a continuous process, troubleshooting, regular maintenance and long-term maintenance are essential. CAMS is the first and only air quality monitoring site in Bangladesh, which is equipped with very sensitive and sophisticated systems. The AQMP staffs were trained only for 15 days per person. This training period is insufficient for smooth operation and properly maintenance of CAMS.

AQMP can implement some of the QA/QC procedure. It was, however, indicated from SMEC already in 2003 that AQMP needs additional assistance from technical experts to enable to implement internationally recognised QA/QC procedures.

Further analyses of the existing QA/QC system as well as support to upgrade the system as part of the AQMP will be undertaken by NILU during Mission 2.

3.3 Upgrading the monitoring network in Bangladesh

Normally the air quality monitoring programme for a city like Dhaka should be designed to provide on-line data and information transfer with direct /automatically/ online quality control of the collected data. Several samplers and monitors including data collection systems can be applied to make on-line data transfer and control possible.

3.3.1 Monitoring objectives

The main background for the design of such a programme will have to be a discussion and identification of the monitoring objectives. A final definition of the objectives will have to be decided between DoE and the Ministry.

A general objective for the air quality measurement programme (monitoring, sampling and analysis) is often to adequately characterise air pollution for the area of interest, with a minimum expenditure of time and money. The measurement and sampling techniques to be used in each case will be dependent upon a complete analysis of the problem (emission sources, dispersion conditions and the current air pollution situation).

In the city of Dhaka there is a need for a permanent network aimed at characterising the air pollution situation related to the possible impacts from all sources to the population of Dhaka. A secondary objective is to evaluate the importance of the emissions from the traffic and to monitor any possible changes in the pollution load over time (trend analyses).

3.3.2 Upgraded air quality monitoring programme for Dhaka

The first priority for the upgrading of the air quality monitoring programme in Dhaka should be to establish a good quality monitoring system for PM_{10} and $PM_{2,5}$. However, we believe that a complete monitoring programme will also have to include measurements of gaseous pollutants such as CO, NO_2, SO_2, Ozone and VOC.

Data reported in the Environment Statistics (Bangladesh Bureau of Statistics, 2005) indicated that hourly ozone concentrations have approached 400 $\mu g/m^3$ and that the average SO_2 concentration at Mohakhali and at Gulshan exceeded 50 $\mu g/m^3$. This

indicates that there are reasons for continued monitoring of these pollutants together with CO and NO_2 along roads and streets.

Meteorological data are also essential in order to interpret and assess the air quality in the city. The one meteorological station, which is being, operated in an open and fairly representative location of the urban centre of Dhaka meets most of the needs for meteorological data.

3.3.3 Sites and locations

The urban air quality monitoring programme shall normally provide information to support and to facilitate the assessments of air quality in different types of areas to be selected.

To obtain information about the importance of these different contributions it is therefore necessary to locate monitoring stations so that they are representative for the different impacts to all parts of the population. This normally means that more than one monitoring site is needed for characterising the air quality in the urban area. It is also important to carefully characterise the monitoring representativeness, and to specify what kind of stations are reporting data.

An often-used terminology is to classify according to the area type (urban, suburban, rural) where they are located, and according to what type of sources (traffic, industrial, background) dominates the air pollution levels at the station. The background stations are divided into; near-city background, regional and remote background stations.

In Dhaka it will be important to cover the urban background. It seems that there are generally high concentrations, especially of PM, all over the city area. In addition we would recommend to measure concentrations along selected roads or streets were a number of people spend hours of the day. One station should be located downwind from the most polluted industries, such as brick factories.

3.3.4 Available equipment

Information has been given that the World Bank has approved funding of a satellite-monitoring network for PM in Bangladesh. The monitoring network will consist of nine PM stations based on dichotomous samplers. Five of these instruments may be used in Dhaka from March 2006. In addition, the satellite-monitoring network will be provided with 18 AirMetric. Two of these additional AirMetric instruments may also be added to the network in Dhaka. It was also indicated that the World Bank approved one new continuous monitoring station. This station may be located in Chittagong even if there is an urgent need to upgrade the automatic station in Dhaka.

The use of these new instruments should be discussed in more details relative to the objectives and the use of the measurement data.

We will suggest that at least two automatic monitoring stations will be established in Dhaka; one at the presently operated CAMS location and one near one of the busy streets in Dhaka centre. The PM samplers may be used to expand the PM network, and sites for these stations should be selected to represent different microenvironments. (See Appendix B in the Inception report (Sivertsen and Laupsa, 2006a).

3.3.5 Automatic monitoring stations

In addition the above-mentioned extension of the PM programme we have also indicated the need for at least one more automatic station in addition to the Sangsad Bhaban (Continuous Air Monitoring Station, CAMS). The second automatic station should be placed near a major road or street in the city centre.

It is important that these data together with the automatic monitoring of gaseous pollutants will be transferred automatically to a central monitoring laboratory for daily check and control. This may also enable information dissemination and the presentation of daily Air Quality Index to the public.

These automatic monitoring stations should also include monitoring of PM_{10} or/and $PM_{2,5}$ using e.g. beta gauge type monitors. These monitors are relatively simple to operate and need a minimum of calibrations. In addition to the PM monitor(s) these stations also need to be equipped with PM samplers, which are identified as reference instruments for PM. The data from these samplers can only be made available some time after the filters have been collected, and they are normally not operated on a daily basis.

3.3.6 A network of PM samplers

Based on the numbers of PM samplers available at AQMP we will suggest that the sampling network in Dhaka is evaluated and expanded.

We will suggest to keep sampling PM_{10} and $PM_{2,5}$ at CAMS and at the new road side monitoring station. We also believe that AQMP should continue operating the already used or selected sites at:

- Tejgaon (Bitac) (A small industrial area of Dhaka. The instrument should be lifted to about 2 m above roof surface to avoid impact from dust blown form the surface)
- Rajarbag (Urban background station inside the police station in the old town of Dhaka, the air intake should be 2 m above roof surface!)
- Lalbag (Urban/near road site at the roof outside the Lalbag fort)
- Narayongong (Suburban site south of Dhaka for PM_{10} and $PM_{2,5}$ since 2005

We would suggest identifying one site downwind from one of the highly polluted industrial areas. The site should be selected 1 to 2 km downwind (south east of the

industries in winter time). The location should be in a populated or residential area and it should preferably measure PM_{10}.

3.3.7 Screening studies

Before final decisions are taken concerning the establishment of a permanent air quality measurement network in Dhaka we will suggest performing a simple screening study. The objective of this study will be to identify expected average concentration levels and evaluate the spatial gradients of pollutants in Dhaka.

Such studies are being used in many cities as part of the design phase of air quality monitoring systems. The locations for such investigations are selected from three main criteria:

1. Measure in different microenvironments (e.g. road side, urban background, industry area and regional background)
2. Selection of indicators or components to measure at the different microenvironments depending on emission sources
3. Prevailing wind directions for the campaign period

The study is using a combination of passive samplers and handheld samplers. Passive samplers of NO_2, SO_2, VOC and O_3 may be placed in several locations in Dhaka city and some in the surrounding suburban areas. Data from the available network of PM samplers as well as the use of additional Minivol samplers will give information about the daily concentrations of PM_{10} and $PM_{2,5}$.

In addition, grab samples of PM, VOC and CO might be collected in different microenvironments during the screening period. Simple instruments are used to measure short-term or instantaneous concentrations in different microenvironments and to identify background concentrations and potential hotspots.

The screening study will have to be designed and operated together with experts, and it will need a separate project plan, cost estimate and time schedule.

3.3.8 VOC sampling

AQMP has requested that simple VOC measurements by grab samples or by daily-integrated sampling are undertaken in Dhaka. If necessary NILU may prepare a proposal for such studies and present it during the next Mission 2.

4 Task 2: Database for air quality and meteorological data

4.1 Objective

Mission 1 to Dhaka has been requested to assist in the development of databases for air quality and meteorological parameters for easy access and dissemination of data. In order to recommend further work on these topics we will have to evaluate the existing databases and the handling and presentation of data.

4.2 The AQMP data retrieval and data storage

AQMP has installed WinCollect (version 3.1) data retrieval and reporting software. This software can collect the monitoring data automatically from the CAMS station. Both meteorological data and air quality data measured by the monitors are automatically transferred from the CAMS to DoE by midnight every day. WinCollect utilize an MS SQL server.

4.2.1 Data retrieval system

WinCollect is designed to interrogate and control environmental monitoring systems and networks, simplifying the tasks of automatically or manually retrieving and viewing measurement data, collating and storing of data into a database, and the summarising of data into comprehensive reports.

WinCollect includes the ability to remotely view in real time both measurement and diagnostic data and control calibration sequences and other station functions using the Ecotech WinAQMS Data Acquisition System.

Data may be retrieved from a remote computer located anywhere in the world. In Dhaka it is connected to the CAMS via modems and the telephone networks. The problem is that the retrieval system is NOT presently operating.

4.2.2 Data base

The WinCollect software also includes a database that could have been used to a larger degree than presently. It seems from discussions with AQMP experts that the main reason may be a lack of training. The gaseous pollutants from CAMS are since August 2005 not retrieved at all. One reason is that also the monitors are not operating adequately. In this respect there is a need for a total upgrading of the system.

The collected PM data from all the stations are stored in Excel files. Much of the statistics presented in monthly reports are generated in Excel even if WinCollect includes statistical programmes. The Meta information concerning stations, site descriptions and instruments cannot be found in the database.

4.2.3 Meteorological data

The quality of the meteorological data seems adequate. Wind roses are produced every month from the wind statistics in WinCollect. Some statistics have been produced to compare air quality and meteorology. However, there need to be more training in the assessment of air quality using the meteorological data available.

4.2.4 Air Quality data and quality assurance

The AQMP do not perform any manually quality control of the air quality data. The instruments are automatically calibrated every 48 hours through a zero-span check using standard gas cylinders delivered by Scott USA. The daily control of data at the computer centre is not being undertaken as long as the data retrieval system does not work.

Further investigations of the routine calibrations and how data are corrected in the database either at CAMS or after included into the central database at DoE will have to be investigated during Mission 2. Weekly or monthly data plots showing the air quality at each site should also serve as a final control of the data.

4.2.5 Data reporting software

Reports are presently produced by AQMP using the WinCollect system together with MS Excel. The WinCollect consists of the most common tools for performing adequate analyses and reporting (monthly and annual) of air quality measurement data in Dhaka.

Presently DoE and AQMP is using the reporting tools for generating time series as well as wind roses and rolling averages. There is clearly a lack of training in the application of the existing system.

4.3 Recommendations

The automatic data retrieval system has not worked properly since August 2005. The software problem started after a disk crash when the software has to be installed over again. All data are now collected manually from the CAMP station and stored as Excel files on the data acquisition computer.

Since the data retrieval system does not work, AQMP don't manage to use the WinCollect system for analysing and storage of data. The latest imported data to the data retrieval system is august 2005.

4.3.1 Further training using the available tools

First priority actions in order to improve the use of the data retrieval and data base system available at AQMP are to provide more training in WinCollect applications. However, the system will for all future be limited to the measurement and reporting of air quality information collected through samplers and monitors.

For further use of data in air quality assessment and planning there will be a need for an integrated tool with a GIS based database system and models for emission inventories and modelling.

4.3.2 An integrated air quality assessment tool

A main objective of the modern Air Quality Management System is to enable direct data and information transfer, provide information on how much pollution the population is exposed to, establish a basis for strategies to reduce pollution and estimate air pollution impacts from present and future developments.

The integrated Air Quality Management (AQM) platform includes all elements needed to undertake assessment and planning of air quality. One such tool has been developed by NILU; AirQUIS. This system provides the basis for air quality management through an integrated tool for monitoring and emission inventorying, air quality modelling and assessment, enabling forecasting of future air quality and development of cost-effective abatement strategies.

A GIS based database and planning tool
The GIS based AirQUIS system includes several modules that can be selected and applied according to the user's needs. Important common parts are the measurement database, and the graphical user interface including the GIS (Geographical Information System).

The user interface is to a large extent a map interface from which spatial distribution of pollution sources, monitoring stations, measurements, model results and other

geographically linked objects can be presented. The map interface can also be used as an entrance for making queries to the database

The GIS (Geographical Information System) functionality is designed to offer several possibilities for understanding the problems of air pollution.

- The GIS makes it easier to place the air pollution sources at the correct location,
- GIS presentation of area-distributed consumption of fossil fuels and direct emissions gives a good overview of where to expect high impact of air pollution.
- Viewing the measurement stations on a map with the pollution sources give options for evaluating source impacts at the stations
- The GIS makes it easier to search for geographically linked data in the database.
- Model estimates presented on maps give information in all parts of the city.

A management tool of this kind may consist of:

- A manual data entering application,
- An on line monitoring system,
- A module for online data acquisition and quality control,
- A measurement data base for meteorology and air quality,
- A modern emission inventory data base with emission models,
- Numerical models for transport and dispersion of air pollutants,
- A module for exposure estimates and population exposure assessment,

Statistical treatment and graphical presentation of measurements and modelling results can be prepared directly in the assessment tool of this kind.

4.3.3 Conclusions

If DoE/AQMP in the future will limit the studies and assessment of air quality in Dhaka to measurements (sampling and monitoring of air pollutants and meteorology) we will recommend that the WinCollect system will be upgraded and adequate training undertaken. In this case it will be necessary also to undertake training in the use of receptor models and to develop a chemical laboratory for filter sample analyses.

If the objectives are to further develop air quality assessment and planning capability at DoE/AQMP we will recommend that a plan for the establishment of integrated databases and modelling tools are developed including the necessary training needed to operate such systems.

5 Task 3: Data management, analysis and report preparation

5.1 Objective

The NILU mission to Dhaka has been requested to assist AQMP staff in data management, analysis and report preparation for specific target oriented studies with actual preparation of some such reports.

5.2 Available reports and reporting procedures

Reporting procedures available at AQMP was studied during Mission 1. Further input to this task will also be given during Mission 2. The collected data are regularly reported in monthly reports as shown in Appendix C of the Inception report (Sivertsen and Laupsa, 2006a).

Three types of air quality monitoring reports have been suggested:

- Daily Air Quality index (AQI)
- Monthly summary reports
- Annual report

5.2.1 Daily reports

The daily reports produced by AQMP are based on the generation of an Air Quality Index (AQI). This is not presently only used for internal information, and it does not even seem to be generated every day and not in real time. The application of this index is thus limited relative to the normal use of such information.

Procedures for the generation of a daily AQI value were prepared by an international consultant. The AQI is linked to the National Ambient Air Quality Objectives. These are long-term objectives that aim to protect public health. An AQI value less than or equal 100 means the air qualities comply with the objectives. An AQI value greater than 100 means that air quality exceeds the objectives

The AQI is a scale that runs from 0 to 500. The higher the AQI value the greater the level of air pollution. An AQI value less than 100 represents good air quality, while an AQI value over 100 represents unhealthy air quality.

The AQI scale is divided into four categories. A specific colour is assigned to each AQI category. These categories are shown in Figure 3.

AQI value	Color	AQI Category	
		English	Bangali
0-100	GREEN	GOOD	BHALO
101-200	ORANGE	UNHEALTHY	ASHASTHAKAR
201-300	VIOLET	VERY UNHEALTHY	KHUB ASHASTHAKAR
301-500	RED	EXTREMELY UNHEALTHY	ATTADHIK ASHASTHAKAR

Figure 3: Classification of air quality based on estimated AQI values as proposed by the international consultant.

An example of the AQI value as presented on 30 November 2005 is shown in Figure 4.

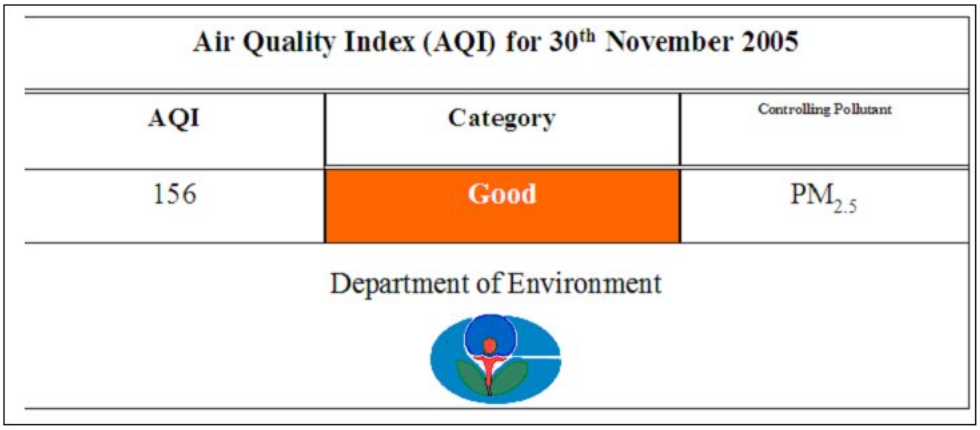
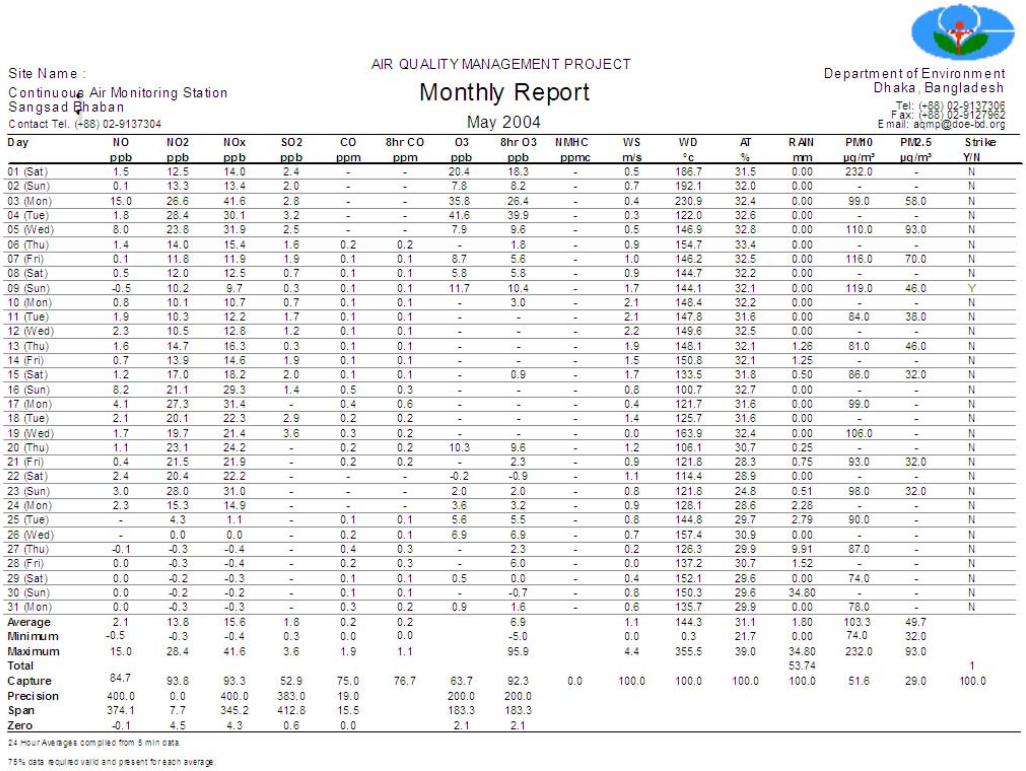


Figure 4: Dhaka Air Quality Index (AQI) as presented on 30 November 2005 based on air quality parameters measured at Continuous Air Monitoring Station (CAMS), Sangsad Bhaban

It can be seen from the figure that local authorities has changed the classification, which is not in accordance with international procedures. This will have to be changed back again.

5.2.2 Monthly summary reports

A monthly summary report has been prepared by AQMP. The example below is from May 2004.



Site Name :
Continuous Air Monitoring Station
Sangsad Bhaban
Contact Tel. (+88) 02-9137304

AIR QUALITY MANAGEMENT PROJECT
Monthly Report
May 2004

Department of Environment
Dhaka, Bangladesh
Tel: (+88) 02-9137306
Fax: (+88) 02-9127952
Email: aqmp@doe-bd.org

Day	NO ppb	NO2 ppb	NOx ppb	SO2 ppb	CO ppm	8hr CO ppm	O3 ppb	8hr O3 ppb	NMHC ppmc	WS m/s	WD °c	AT %	RAIN mm	PM10 µg/m³	PM2.5 µg/m³	Strike Y/N
01 (Sat)	1.5	12.5	14.0	2.4	-	-	20.4	18.3	-	0.5	186.7	31.5	0.00	232.0	-	N
02 (Sun)	0.1	13.3	13.4	2.0	-	-	7.8	8.2	-	0.7	192.1	32.0	0.00	-	-	N
03 (Mon)	15.0	26.6	41.6	2.8	-	-	35.8	26.4	-	0.4	230.9	32.4	0.00	99.0	58.0	N
04 (Tue)	1.8	28.4	30.1	3.2	-	-	41.6	39.9	-	0.3	122.0	32.6	0.00	-	-	N
05 (Wed)	8.0	23.8	31.9	2.5	-	-	7.9	9.6	-	0.5	146.9	32.8	0.00	110.0	93.0	N
06 (Thu)	1.4	14.0	15.4	1.6	0.2	0.2	-	1.8	-	0.9	154.7	33.4	0.00	-	-	N
07 (Fri)	0.1	11.8	11.9	1.9	0.1	0.1	8.7	5.6	-	1.0	146.2	32.5	0.00	116.0	70.0	N
08 (Sat)	0.5	12.0	12.5	0.7	0.1	0.1	5.8	5.8	-	0.9	144.7	32.2	0.00	-	-	N
09 (Sun)	-0.5	10.2	9.7	0.3	0.1	0.1	11.7	10.4	-	1.7	144.1	32.1	0.00	119.0	46.0	Y
10 (Mon)	0.8	10.1	10.7	0.7	0.1	0.1	-	3.0	-	2.1	148.4	32.2	0.00	-	-	N
11 (Tue)	1.9	10.3	12.2	1.7	0.1	0.1	-	-	-	2.1	147.8	31.6	0.00	84.0	38.0	N
12 (Wed)	2.3	10.5	12.8	1.2	0.1	0.1	-	-	-	2.2	149.6	32.5	0.00	-	-	N
13 (Thu)	1.6	14.7	16.3	0.3	0.1	0.1	-	-	-	1.9	148.1	32.1	1.26	81.0	46.0	N
14 (Fri)	0.7	13.9	14.6	1.9	0.1	0.1	-	-	-	1.5	150.8	32.1	1.25	-	-	N
15 (Sat)	1.2	17.0	18.2	2.0	0.1	0.1	-	0.9	-	1.7	133.5	31.8	0.50	86.0	32.0	N
16 (Sun)	8.2	21.1	29.3	1.4	0.5	0.3	-	-	-	0.8	100.7	32.7	0.00	-	-	N
17 (Mon)	4.1	27.3	31.4	-	0.4	0.6	-	-	-	0.4	121.7	31.6	0.00	99.0	-	N
18 (Tue)	2.1	20.1	22.3	2.9	0.2	0.2	-	-	-	1.4	125.7	31.6	0.00	-	-	N
19 (Wed)	1.7	19.7	21.4	3.6	0.3	0.2	-	-	-	0.0	163.9	32.4	0.00	106.0	-	N
20 (Thu)	1.1	23.1	24.2	-	0.2	0.2	10.3	9.6	-	1.2	106.1	30.7	0.25	-	-	N
21 (Fri)	0.4	21.5	21.9	-	0.2	0.2	-	2.3	-	0.9	121.8	28.3	0.75	93.0	32.0	N
22 (Sat)	2.4	20.4	22.2	-	-	-	-0.2	-0.9	-	1.1	114.4	28.9	0.00	-	-	N
23 (Sun)	3.0	28.0	31.0	-	-	-	2.0	2.0	-	0.8	121.8	24.8	0.51	98.0	32.0	N
24 (Mon)	2.3	15.3	14.9	-	-	-	3.6	3.2	-	0.9	128.1	28.6	2.28	-	-	N
25 (Tue)	-	4.3	1.1	-	0.1	0.1	5.6	5.5	-	0.8	144.8	29.7	2.79	90.0	-	N
26 (Wed)	-	0.0	0.0	-	0.2	0.1	6.9	6.9	-	0.7	157.4	30.9	0.00	-	-	N
27 (Thu)	-0.1	-0.3	-0.4	-	0.4	0.3	-	2.3	-	0.2	126.3	29.9	9.91	87.0	-	N
28 (Fri)	0.0	-0.3	-0.4	-	0.2	0.3	-	6.0	-	0.0	137.2	30.7	1.52	-	-	N
29 (Sat)	0.0	-0.2	-0.3	-	0.1	0.1	0.5	0.0	-	0.4	152.1	29.6	0.00	74.0	-	N
30 (Sun)	0.0	-0.2	-0.2	-	0.1	0.1	-	-0.7	-	0.8	150.3	29.6	34.80	-	-	N
31 (Mon)	0.0	-0.3	-0.3	-	0.3	0.2	0.9	1.6	-	0.6	135.7	29.9	0.00	78.0	-	N
Average	2.1	13.8	15.6	1.8	0.2	0.2		6.9		1.1	144.3	31.1	1.80	103.3	49.7	
Minimum	-0.5	-0.3	-0.4	0.3	0.0	0.0		-5.0		0.0	0.3	21.7	0.00	74.0	32.0	
Maximum	15.0	28.4	41.6	3.6	1.9	1.1		95.9		4.4	355.5	39.0	34.80	232.0	93.0	
Total													53.74			1
Capture	84.7	93.8	93.3	52.9	75.0	76.7	63.7	92.3	0.0	100.0	100.0	100.0	100.0	51.6	29.0	100.0
Precision	400.0	0.0	400.0	383.0	19.0		200.0	200.0								
Span	374.1	7.7	345.2	412.8	15.5		183.3	183.3								
Zero	-0.1	4.5	4.3	0.6	0.0		2.1	2.1								

24 Hour Averages compiled from 5 min data.

75% data required valid and present for each average.

Figure 5: A monthly summary report showing daily data of gases, particulate matter and meteorology for May 2004.

The monthly report should also include data recovery statistics. Some basic air pollution statistics as well as wind roses and exceeding of standards should be part of this report. A typical monthly report as prepared for November 2002 was presented in Appendix D of the Mission report. We could not see that these reports had been generated during the last year(s).

5.2.3 Annual report

As far as we were informed the annual report has only been prepared to the World Bank with the support of an international consultant. This report contained data from 2002 and 2003.

The report represented a combination of raw data and statistics. Monthly average concentrations as well as number of days with exceedances were presented.

An example of figures taken from this annual report is presented below. Figure 6 shows that the average PM_{10} concentrations measured at CAMS were considerable higher during the dry season than in the wet season. The ratio between monthly averages measured in January and those measured in July was more than 5.

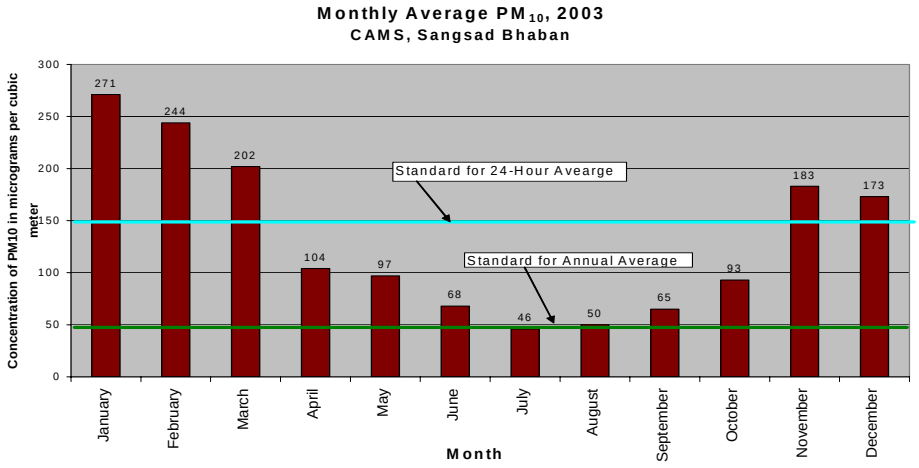


Figure 6: Monthly average concentrations of PM_{10} measured at CAMS during 2003.

Figure 7 shows that the measured $PM_{2.5}$ concentrations in January were exceeded on 30 out of 31 days.

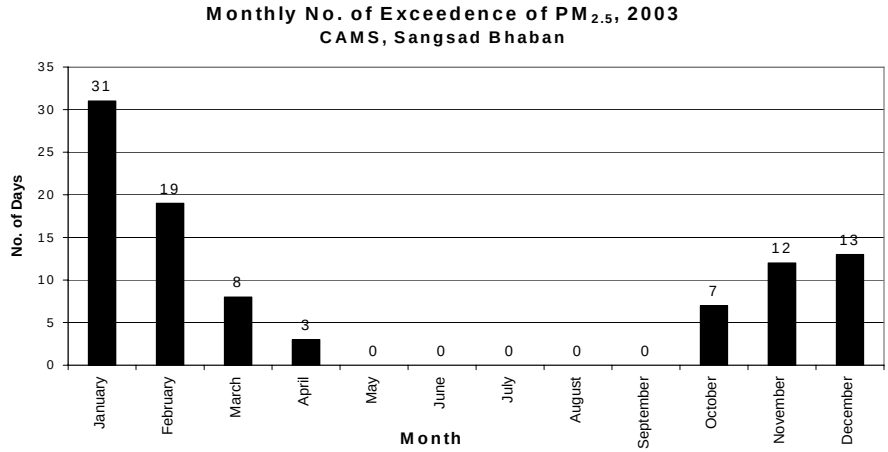


Figure 7: Number of days during each month of 2003, when $PM_{2.5}$ concentrations at CAMS exceeded the air quality objectives for Bangladesh.

In the database at AQMP there are also a number of figures prepared in excel. These figures did not seem to have been used in reports. AQMP has operated the air quality monitoring in Dhaka at CAMS since April 2002. The results of the monitoring have shown that $PM_{2.5}$ and PM_{10} concentrations are the major issue. Particularly in the non-

monsoon period the concentration of $PM_{2.5}$ and PM_{10} exceed the proposed standard regularly.

Figure 8 show an example of figures available in the database. It shows the PM_{10} concentrations as measured at Sangsad Bhadan (CAMS) from April 2002 to June 2004.

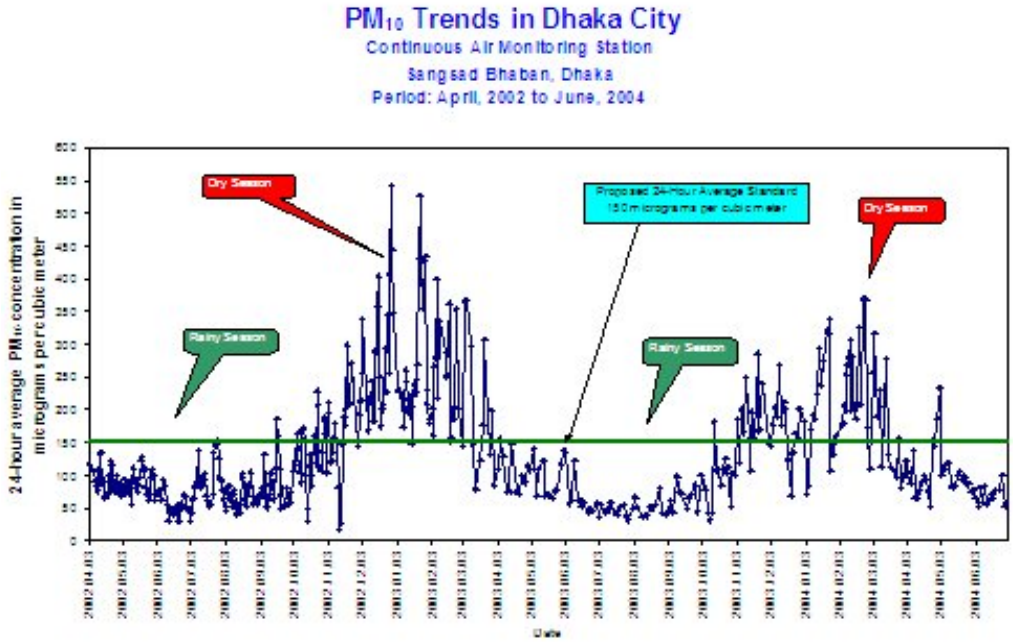


Figure 8: PM_{10} concentrations ($\mu g/m^3$) measured on a daily basis at Sangsad Bhadan Dhaka from April 2002 to June 2004.

The long-term trend in PM_{10} concentrations has been evaluated, and it was stated that there has been a slight decrease in particulate matter concentration in the ambient air from 2002 to 2003. Probably the phase out of two-stroke three-wheeler is one of the causes of this reduction.

5.2.4 The air quality assessment tool at AQMP

The AQMP is using the WinCollect software for data retrieval and data reporting. The software is an adequate tool for quality control and air quality assessment. The data assessment may be conducted in a rational and user-friendly way. However, there has been identified some weakness in the routines of data retrieval and quality control, and parts of the system did not function properly during Mission 1.

We have observed that much of the statistics and basis for the reporting has been prepared in MS Excel. The software system WinCollect has thus only been applied to a very limited amount in the assessment of the air quality of Dhaka. We have mentioned that further training is needed to manage to fully use the system.

5.3 Recommendations

5.3.1 Reporting requirements under DoE

Reporting requirements should be discussed with the Ministry of Environment. The air quality investigations and reporting procedures available at AQMP should meet the needs and requirements stated by the Ministry. We will recommend that the work performed by DoE/AQMP will be closer linked to the needs of the Ministry.

We have seen that the classification of the air quality based on the AQI procedures has been changed relative to international procedures (see Ch. 5.2.1). This will have to be discussed with the Ministry again and changed back to the original proposals as given by international consultants from SMEC International.

We will propose that AQMP call a meeting with the responsible persons in the Ministry to present the status of AQMP, the data available and what reports can be produced. There is also a need for the Bangladesh Government to establish a separate division for Air Quality under DoE to handle air pollution monitoring and management issues in the future.

5.3.2 The assessment tools

Standardised statistical analysis should be performed to assess air quality trends, changes in emissions or impact from specific types or groups of sources. The severity of the air pollution problem or the air quality should be specified relative to air quality limit values, standards or pre defined levels of classification (e.g. good, moderate, unhealthy, hazardous).

This will also need minimum requirements of a data base completeness. Long-term averages (annual or seasonal) should be presented relative to limit values.

Air quality data are visualised in different ways based on different types of statistics. Some of the typical presentations may be:

- Time series and average concentrations,
- Cumulative frequency distributions, where the frequency distribution should be referred to air quality standards,
- Average concentration distributions at various monitoring sites as function of wind directions (Breuer diagrams or concentration "roses", polar plot),
- Scatter plots which can be used for interrelation between simultaneous air quality measurements, meteorological variables or other relevant data,
- Average concentration as function of time of day.

All these requirements need a proper assessment tool. The solution to these challenges, in addition to using state-of-the-art technical solutions in all parts of the systems, is to ensure a common core of know-how, technical specifications and quality assurance.

5.3.3 Upgrade existing system

First of all is there a lack of support and knowledge to maintain the WinCollect data retrieval and reporting system. Without any adequate support or knowledge to maintain and manage the system, the system will stop when technical problems occur.

As far as we understand, there is not a routinely based manual quality control of the data collected. This is an operational procedure that should be performed to identify as early as possible data errors, data collection- and instrument problems.

The automatically zero and span check preformed every 48 hours and the manual checks that is carried out every 2 weeks have to be brought into the correction of the final approved database.

As mentioned several times more training is needed in the general data assessment and use of the management tool. Not all the features of the data retrieval and data reporting system are utilized for performing a comprehensive data assessment.

5.3.4 Data handling and presentation

Generation of the necessary statistics which should be part of the monthly and annual reports have to be simplified and updated through training in the use of the available databases at AQMP. The monthly and annual reports should be evaluated and we suggest that the design of these reports is discussed so that they will meet the needs of the Ministry of Environment as well as requirements given for reporting e.g. from the European Union or US EPA.

For further assessment of air quality in Dhaka an integrated assessment tool including measurement data (air pollution and meteorology), emission inventories and models such as indicated in Ch.4.3.2 above should be established at AQMP. This will enable more automatic report generation of such as daily air quality index, monthly statistics and annual reports. It will also give a more complete picture of the status of air quality in Dhaka.

In the future it may also be possible to disseminate this information to the public, to forecast air pollution and the perform impact assessments and planning.

6 Task 4: Terms of references for small and medium sized enterprises

6.1 Objective

The Mission experts have been requested to assists in the development of the Terms of reference (ToR) for small studies as well as to train and assist AQMP with one or more field studies such as at **Brick Kilns**. We may also assist AQMP staff in preparation of reports and in the development of ToR for future investigations of this kind.

6.2 Status and actions

The AQMP staffs have not the proper tools, input data or dispersion models for performing simple preliminary impact assessment studies at polluting industries such as brick kilns. AQMP also seems to lack the basic knowledge and background for performing these kinds of investigations.

As part of the training the NILU experts together with the AQMP staff visited an area of brick kilns in the northwestern part of Dhaka. The data collected as well as the preliminary results of these studies as presented in a seminar the day after the site visit is presented blow.

The AQMP staffs were shown how to prepare and produce simple reports for specific target oriented studies of this kind. Some data on these types of industries are available through the permits issued by DoE. A simple Gaussian type dispersion model was also used to generate downwind concentrations from the brick factories. This action was considered part of the initial training in the understanding and use of dispersion models. The model was after the seminar given (free of charge) to the staff at AQMP. The introduction to this model is presented in Appendix C

6.3 A brick kiln area visited and reported

One of the brick kiln area in the outskirt of Dhaka consisting of about 108 stacks (furnaces) was visited. The main objectives of the visit were to collect information

regarding how a brick kiln area is organised and collect data needed for emission and dispersion modelling.

Prior to the visit AQMP had received some information concerning the permits given by DoE for the specific brick kiln area located in the Gabtali area north west of the city centre of Dhaka.

Figure 9: The brick kiln area around Gabtali consists of 108 stacks each between 40 and 50 m high.

We were also told that there are approximately a total of 4000 brick kilns in the surroundings of Dhaka.

We visited two separate brick kilns. The first one was H&Co where two kilns and two stacks were located at a distance of about 100 m from each other. The other factory was the Sonali brick factory with one kiln/stack. The second was the located about 500 m west of the first kiln visited.

6.3.1 Kiln data

The brick kilns need a licence (environmental certificate) to operate. The DoE performs annual inspections. The annual inspections verify the fuel used and the stack height. The only environmental demands are the stack height, which has to be more than 120 feet (approx. 40 m).

All the brick kilns have stacks ranging between 120 and 135 feet (40-45m). The stack outlet diameter is approximately 1-1.5 m. One of the kiln operators claimed that the only fuel used is coal (approximately 90 %). Some wood fuels are used for kindling. The fuel is low quality coal from India.

The sulphur content was assumed to be approximately 3-4% and the ash content is between 20 and 30 %. For evaluation of a potential plume rise due to heat emissions and momentum we observed several plumes. We could not see any significant plume rise and assumed that the exit gas temperature was near ambient temperature.

Figure 10: A Hoffman type furnace where coal is fed into the kiln through holes from above.

The owners have no knowledge about environmental pollution like sulphur content and emissions. They have never heard about complaints from neighbours due to the heavy burden of particles and other pollutants in the vicinity of the factories.

The furnace we were looking at was a so-called Hoffman type brick kiln. The amount of coal used for each kiln is approximately 4-6 tons/day. The production rate was approximately 22 000 bricks/day.

At each kiln there were approximately 250 employees. The coal was transported to the brick kiln area by trucks from India. The trucks were in very bad conditions and emit a large amount of pollutants. Black smoke is surrounding these trucks.

They are not allowed to enter into the city centre of Dhaka. The trucks also represent an important emission source and contribute to the general air pollution concentration level near the ground in the area. The kilns are only operated in the dry

season, from November until April. During the rainy season the brick kiln area is flooded and new clay is deposited. One of the operators told that natural gas had been used as fuel before, but lack in supply forced them to change to coal.

6.3.2 Preliminary analysis of the environmental impact of the brick kilns

NILU performed a preliminary impact study to demonstrate the use of a simple model and to present and discuss the expected ground level concentrations of SO_2 (and PM?) downwind from the brick factory. The model used is presented in Appendix C. The following input data was prepared:

Fuel used:	Mainly coal
Consumption:	about 4 tons/day
Production:	~ 22 000 bricks/day
Sulphur content:	3-4 % S
Ash content:	20-30 %
Stack height:	45 m
Outlet stack diameter:	~ 1 m
Exit gas temperature:	about at ambient
The estimated emission rate of SO_2 is:	3.2 g/s

The simple dispersion model (CONCX) was run for a single kiln using different meteorological conditions (stable, neutral and light stable atmospheric conditions for different wind speeds). The results in Figure 11 show the concentration of SO_2 from at different distances downwind from a single kiln.

In addition to the single source estimate a simple modelling study was preformed for 33 brick kilns to evaluate the total impact downwind from the whole brick factory area of Gabtali. Dispersion modelling was perform for 33 randomly distributes kilns in the area assuming meteorological conditions for a normal winter day with stable condition during night, fairly unstable daytime conditions and prevailing wind directions from around north and northwest.

The results presented in Figure 12 shows the daily average concentrations for each square km grid cell. The calculation was preformed using the models available in the AQM system AirQUIS.

The preliminary model results show that the highest impact from the brick factory area may be inside the first two kilometres southeast of the factory area. The estimated daily average concentrations of SO_2 over the city area were estimated to about 10 to 20 $\mu g/m^3$. Most of this impact occurred during nighttime when the atmosphere was stable and low wind prevailed. This estimate assumed 33stacks. For the total of 108 stacks the impact will be larger than the ones presented in Figure 12.

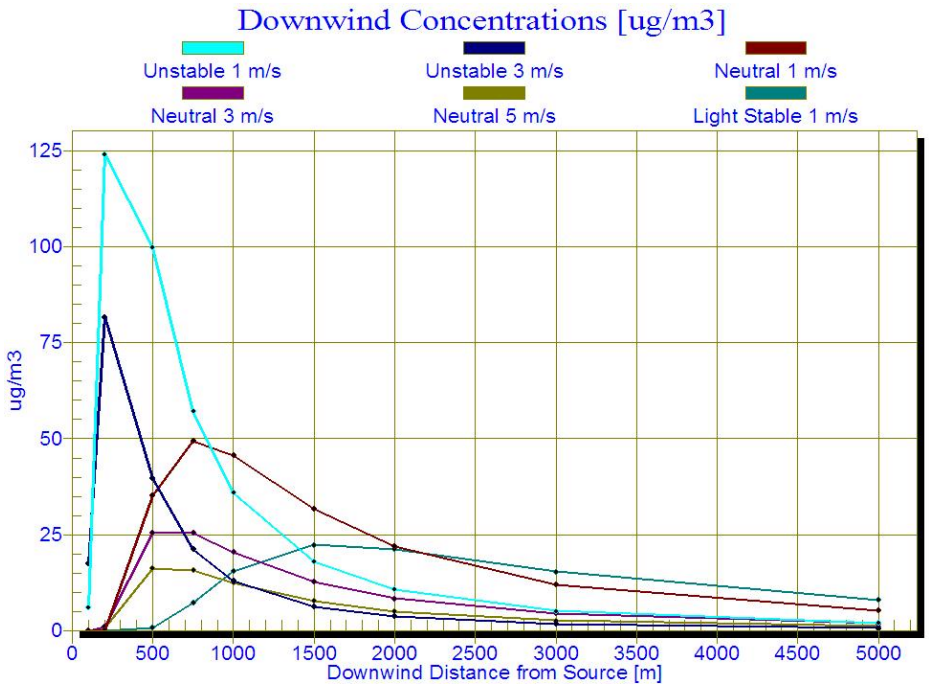


Figure 11: Estimated SO_2 concentrations ($\mu g/m^3$) at different distances downwind from a brick kiln under different meteorological conditions.

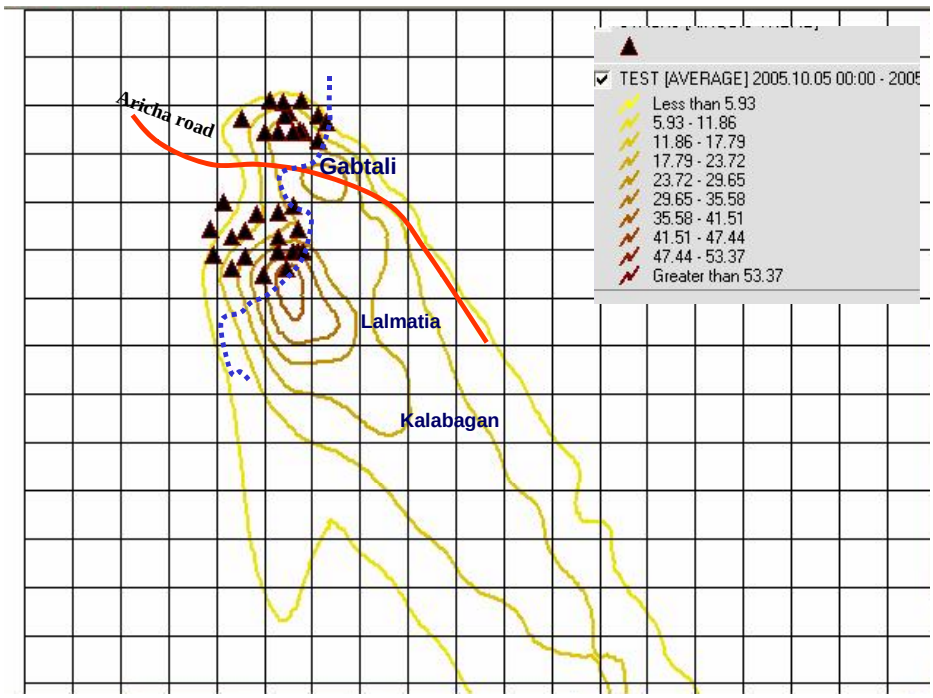


Figure 12: Estimated SO_2 concentrations in square kilometres downwind from 33 brick kilns located northwest of the city centre of Dhaka. The meteorological data were typical for a winter day in Dhaka.

6.4 Recommendations

6.4.1 Collect data

AQMP was given Excel based templates for starting the collection of emission data (see Ch. 8 Task 6). In addition the NILU experts gave training to some of the AQMP staff on how to collect emission inventory data for point sources. Based on this basic information it should be possible to start the collection of brick kiln information.

6.4.2 The impact must be evaluated for a multiple of sources

To perform an air pollution impact study at the brick factories will require that AQMP can perform the study for a multiple of sources. As a start it may be important to look at the concentration downwind from one single source. However, the emissions and the plumes from these factories, which are located quite close to each other, are so interacting with each other that it will be necessary to see the whole area as a large area of multiple sources.

One way of starting such a study is to perform a kind of screening study using simple measurement equipment. The design of such a study must rely on some simple model estimates as well as information about prevailing wind and dispersion conditions. The preliminary estimates performed for the brick factories visited during Mission 1 could be used as guidance.

6.4.3 Perform simple measurements

We believe that it will be necessary to perform some measurements downwind from the brick kilns in order to evaluate the relative importance of the emissions from the stacks. Exact locations of samplers and instruments will be important, as we have seen that there are also considerable amount of dust and fumes emitted from activities at the surface, such as from the highly polluting trucks.

The design of the measurement programme is important in order to get specific results. It may even be necessary to release a tracer in the brick kilns to follow this through the stack, into the atmosphere and sample it at the surface at different distances from the stack. NILU has performed a number of such studies. Ground level measurement data together with modelling will enable to quantify the relative contribution from the specific industry in question.

Another method may be to obtain a “fingerprint” of elements and pollutants emitted from the specific factory and then perform multiple element analyses on filters sampled downwind from the industry using e.g. AirMetrics instruments.

6.4.4 Model estimates by AQMP

The AQMP staffs did not have access to dispersion models. The background as well as knowledge and training for doing modelling for impact assessment were also lacking. The model exercises performed during Mission 1 was mainly an introduction to the use of models and what kind of data and information is needed to perform simple impact statements around small factory areas like brick factories.

During the seminar we presented the data input and gave an introduction to how simple Gaussian plume models works. In a smaller workshop we also demonstrated and trained some of the staff in using this model. We finally installed the NILU developed CONCX model on two of the computers at the DoE. Some of the AQMP staff would thus manage to carry out similar evaluations of single industries.

From this little training programme and the tools given to AQMP, it should be possible to perform simple model estimates as long as emission data and necessary input data are available.

6.4.5 Prepare ToR

A Terms of Reference for the impact from a small industry such as a brick kiln may be prepared. However, it may be necessary to identify this single industry (single stack), industrial complex or industrial area before an adequate ToR can be developed.

The elements mentioned above are clearly the necessary input to the ToR. An example is presented in Appendix D.

7 Task 5: Updating the training plan for AQMP/DoE staff

7.1 Objective and background

Based on the available information on training and institutional building the experts will assist in updating a training plan for Air Quality Management for AQMP/DoE staff.

The primary objective of the air quality related projects in Bangladesh is to develop components of an air quality management system to reduce human exposure to air pollution in Dhaka. So far these plans have been closely related to the improvement of vehicles to reduce traffic generated air pollution. One element of controlling this target is to improve the air quality monitoring and assessment capability. Training in the use of the databases and planning tools available including the air pollution modelling capability will also help to improve the institutional capacity for air pollution planning and abatement.

7.2 Status

The training given to the AQMP team was mainly based on the operation of monitoring equipment. The AQMP staffs were trained only for 15 days per person. Other elements of the institutional building adequate for establishing the knowledge to perform air quality assessment and management has never been given to the staff at AQMP.

The AQMP staffs is not involved in the ongoing training program for Bangladesh Environmental Management Project (BEMP), which is a joint project of the Government of Canada and the Bangladesh Department of Environment, funded by the Canadian International Development Agency (CIDA). This programme does not seem to include air pollution at all.

The AQMP/(DoE??) staff needs support and training to maintain sustainability and to development the AQM work for Dhaka.

The training needs assessment was discussed with the AQMP staff, and some of the conclusions from these discussions are reported in the next chapter.

7.3 Much more training is needed

A considerable amount of training will have to be planned and undertaken to bring the AQMP staffs up to the level when they will be able to perform assessment and air quality management studies. Even for the operation, maintenance and quality assurance of the monitoring system we believe that much more training is needed.

Some of the training elements that was discussed with AQMP included:

- Air quality monitoring and QA/QC
- Databases and data assessment
- Emission inventories
- Screening studies/small industries
- Dispersion models and modelling
- Receptor modelling
- Air Quality Management

These training elements will be discussed in the following.

7.3.1 Monitoring and QA/QC

We recommend that further training will be given in the operations of the continuous monitors to be operated at CAMS. Both the instrument features as well as operations, maintenance and some input in repair procedures should be part of this training.

The training could be undertaken by instrument providers/dealers or by the manufacturers. For some monitors there are courses held at the factory, which the instrument providers may partly pay.

Expert institutions can also provide some training; these should have expert personnel (instrument and electronic engineers) who are used to operate such instruments.

Concerning the QA/QC training it will be important to obtain all the documentations in the form of instrument guidelines, standard operations procedures (SOP), instrument and history logbooks etc.

The NILU instrument expert will give some of the input to this part of the training programme during Mission 2. NILU may also in the future give lectures and on the job training in running and operating the monitoring network. This will consist of establishing procedures for operation and calibration at the station and maintaining the standard operational procedures at the station

7.3.2 Databases and data assessment

As a first priority we will recommend that the WinCollect system will be upgraded and adequate training undertaken. The institution providing this system should be able to perform this part of the training programme.

If the objectives are to further develop air quality assessment and planning capability at DoE/AQMP we will recommend that a plan for the establishment of integrated databases and modelling tools are developed including the necessary training needed to operate such systems. This part of the training in the use of the databases may be integrated in the air quality modelling and assessment training programme. NILU is undertaken this kind of training, and a training programme may be a combination of a standard introductory programme at NILU as well as hands-on training in Dhaka.

7.3.3 Emission inventories

An introduction to emission inventories was given at a seminar arranged at the DoE on 23 January 2006. The lecture was a general introduction to emission inventory and some brief examples were presented on which data are needed to make a bottom-up inventory (Sivertsen and Laupsa, 2006b).

A separate workshop concerning emission inventories was arranged at the DoE on 24 and 25 January 2006. Eleven persons attended the workshop and the list of participants is given in Appendix A. The objectives of this workshop was to give a more detailed presentation in how to prepare an emission inventory and to introduce the AQMP staff to one type of the emission inventory templates for collecting emission data.

If AQMP in the future chose to proceed using the AirQUIS database for emission data, further training will be given in form of seminars, workshops and on-the-job training as part of the air quality management institutional building (See Ch. 7.3.7.)

7.3.4 Screening studies/small industries

The AQMP staffs were shown how to prepare and produce simple reports for specific target oriented studies at small industries as presented in Ch. 6.3. In order to introduce the staff at AQMP to simple single source dispersion modelling the NILU developed CONCX model was used to generate downwind concentrations from the brick factories.

The model was after the seminar given to the staff at AQMP. In addition to the brief introduction to the model presented in Appendix C, more training is needed for modelling as presented below.

To perform screening studies may best be trained through hands-on training by actually performing a study of this kind. We have indicated how to undertake such a study for a

brick factory area. We will thus propose that the team at AQMP actually undertook, together with an international expert team, a field study at one selected industrial area.

7.3.5 Dispersion models and modelling

A wide range of different atmospheric dispersion models is available on the marked and can be purchased. However, air pollution modelling is not a question of having a model but of understanding the physical processes in the atmosphere so that relevant data can be prepared as input. The interpretation and understanding of the output is also necessary to be able to adequately run and use dispersion models.

For this purpose it will be necessary that local experts are being trained in the use of models. These experts should preferably have theoretical background in geophysics, mathematics, meteorology or fluid mechanics. Models can be distinguished on many grounds: e.g. the underlying physical concepts, the temporal and spatial scale, and type of component. Contemporary air pollution models deal with "conventional" primary pollutants (mainly SO_2, CO, NO_x and VOC).

Training in the use of dispersion models is thus highly dependent upon what kind of model is to be applied. General input to modelling can be obtained at the universities or at training courses arranged by various organisations and International Banks. We will propose that the experts selected to run models at DoE follow courses held by providers of models.

7.3.6 Receptor modelling

The main objectives in performing receptor modelling or source apportionment methodologies will be to quantify source contributions by sector so that appropriate policies can be drafted. Receptor models normally give the relative contributions of different sources at the site where measurements are collected.

Studies have been undertaken at the Atomic energy centre in Dhaka to quantify contributions to fine particulates ($PM_{2,5}$) and coarse particulates (PM_{10}) as well as primary and secondary pollutants at three sites in Dhaka.

Training in the use of receptor models by AQMP/DoE could be obtained through a co-operation between the Atomic energy centre and DoE. The training should include a review of source apportionment methodologies employed in the developing countries as well as the application of such models. Some of the methods frequently applied are Chemical Mass Balance (CMB), enrichment factors (EF), temporal and spatial correlation methods (e.g., PCA, FA, EOF), neural networks and time series (e.g., spectral analysis, intervention analysis, lagged regression analysis).

The background for undertaken these modelling studies is, however, that equipment is available for multi element analyses of filters collected by high volume samplers in the AQMP programme.

7.3.7 Air Quality Management

If the main objective is to lift the AQMP staff to perform complete air quality assessment and management studies this will require basic institutional building in addition to the training of operation of the measurement system and simple screening studies and single source modelling.

Capacity building and training must in this case be combined through seminars, workshops and on the job training

General institutional strengthening through environmental quality lectures and seminars will be undertaken and designed specifically for the needs for Dhaka and Bangladesh. The information and data collected from the monitoring of air quality in Dhaka will ultimately be used to improve the environmental quality in Dhaka.

The program will give valuable information on the air quality situation and assessment on how the situation is compared with national and international air quality standards. This will be used to make a plan of action for measures to reduce emissions and reduce air pollution in Dhaka. The information from the project will be a good basis for making decisions on environmental pollution reduction measures.

The general capacity building of this kind normally starts with a kick-off seminar. The first part of this seminar may be directed also to stakeholders, but this will have to be discussed with DoE. The seminar will introduce the total monitoring and management system and explain the various elements of such a system.

The training on development of platforms, monitors, models and assessment tools will be performed through on the job training and discussions between expatriate experts and local experts as the work proceeds. The main part of the monitoring training was discussed above in Ch 7.3.1.

Before going into the capacity building and training activities, a few comments to the training elements are needed.

The air quality management platform
Before this advanced training and institutional building starts the DoE/AQMP will have to decide on the database and management platform to use.

The following procedures are based on the NILU developed **AirQUIS platform.**
The selection of other platforms may result in a slightly different training programme.

If AirQUIS has been selected two to three experts from the DoE will be invited to Norway for a 6 weeks training session. Working with the system used for emission inventorying, data retrieval, databases, data treatment and presentation, as well as dispersion and exposure modelling will be part of this training.

Modelling and data interpretation skills will have to be evaluated. Air quality data statistics including the use of meteorological data in air quality interpretation and presentation will have to be prepared. Procedures for air quality impact assessments will be presented.

The information and data collected from the monitoring stations will ultimately be used to improve the environmental quality in Dhaka. The program will give valuable information on the air quality situation and assessment on how the situation is compared with air quality standards.

The needs for capacity building will therefore combine practical field operational work, modelling which includes emission data collection and lectures on "understanding air pollution". These activities will be conducted in coordination with the local authorities and the end users.

The new database and assessment centre will be established at DoE in Dhaka. In addition to data management, training will include tutorials on the basic concepts and techniques of air quality monitoring and reporting.

Most of the training will take place in Dhaka in the form of seminars, workshops and on-the-job training.

A summary of capacity building and training activities for the air quality assessment and management component.

Topic	Forum	Trainees
Introduction to the total Air Quality management system	Kick-off seminar	Experts from AQMP
Understanding air quality and the AirQUIS platform	On-the-job in Dhaka, Training at NILU	AQMP experts who will operate the system in the future
Data retrieval and QA/QC	On-the-job in Dhaka, Training at NILU	Experts from AQMP/DoE
Establish complete emission inventories	Workshop and on-the-job	AQMP computer experts
Run air quality dispersion models	Workshop and on-the-job	Experts at AQMP/DoE to run future models
The use of models in air quality planning and abatement strategies	Intro Seminar/ Workshop	AQMP experts
Air quality monitoring and assessment. Meet Norwegian institutions and Authorities	Meetings and seminars in Norway	Experts from MoE/DoE and AQMP
Data treatment, reporting, data dissemination.	Workshop, On-the-job	Experts and users

Further training needs will also be identified during the development and operation of the project.

8 Task 6: Emission inventory database for Dhaka city

8.1 Objective

The NILU experts will help AQMP staff to start to collect source data in order to perform an air pollution emission inventory for Dhaka city. The basic methodology for the development of an emission inventory **(**EI) database was presented in a seminar and some initial training has already been given to the AQMP staff during Mission 1.

8.2 Background and status

AQMP did not have any emission inventory for Dhaka and there is as far as we have been told no existing overview of the most important emission sources and locations. No emission data are collected and traffic emission factors for Bangladesh is not available. When we arrived the DoE/AQMP did not have any tools or methods for preparing and utilize an emission inventory.

The NILU experts arranged a seminar on 23 January 2006 at the DoE. During this seminar we gave a brief introduction to the emission inventory system. The lecture was a general introduction to emission inventory and some brief example of which data needed to make a bottom-up inventory was given (Sivertsen and Laupsa, 2006b).

An additional workshop concerning emission inventory was arranged at the DoE on 24 and 25 January2006. Eleven persons attended the workshop and the list of participants is given in appendix A. In this workshop we gave a more detailed presentation in how to prepare an emission inventory and to introduce the AQMP staff to one type of the emission inventory templates for collecting emission data.

8.3 Introduction to an emission inventory

To be able to assess the air pollution problems, and to work effectively towards their management and reduction, one of the first and main prerequisites is to have quantitative information about the sources and the amount and types of emitted compounds.

Information on pollutant emissions is usually compiled in emission inventories. These are complete and exhaustive lists of emission sources and air pollutants referred to specific geographical areas in defined periods of time.

Emission inventories are used in air quality management mainly in two ways:

1. The inventory shows which types of, and which individual sources are responsible for most of the emissions of each substance, as a basis for the first step in reducing the air pollution problem.

2. The inventory is used as input to dispersion models, which calculates the contributions to the air pollution concentrations from each source/source type. For this use, exact information on source locations, stack height and other emission data, such as time variation of the emission, is needed.

For the urban emission inventory to be as useful as possible, it is important to include the spatial and temporal distribution of the sources. In practice, atmospheric emissions are estimated on the basis of measurements made at selected or representative samples of the (main) sources and source types. In addition the inventory may be based on statistics regarding the number of sources and their consumption of fuel/raw material or production rates. These data are then combined with emission factors to estimate emission rates.

8.3.1 Top-down and bottom-up inventories

A *top-down inventory* is characterised by lack of detailed information about location and emissions from individual sources. When fuel consumption, production, vehicle and other activity statistics are available, a top-down inventory can be constructed, using the statistics and emission factors. In a first phase, a top-down inventory can be produced with relatively little effort, to give an overview of the emissions, the most important sources and categories.

The bottom-up inventory is constructed from a more detailed knowledge of source types and locations, and their specific emissions or consumption data. This is the type of inventory, which is at present usually compiled, since it gives a much better basis for air quality management. This type of emission inventories is also needed when atmospheric dispersion models are to be applied in a specified area.

Software tools are available for efficient and user-friendly applications of bottom-up emission inventories. The NILU developed AirQUIS system has implemented functionality for bottom-up inventory.

8.4 The emission inventories templates and the emission inventory database in AirQUIS

A module for the Air Pollution Emission Inventory is integrated in AirQUIS. This module contains the necessary forms and functionalities for producing a complete, detailed atmospheric emissions inventory for a specified area.

The Module is a flexible system to treat the main sources for emission to air. Based upon emission inventory input data collected externally to the system, the module administers the input into the structure of the Emission Inventory Module. The system is GIS based and the emissions can be separated on area basis (different administrative region levels or on grid). The system also administrates supporting data such as emission factors; production rates and various source sectors.

The emission inventory module includes all type of emissions data and the module contains data on three types of sources, namely point, area and line.

Point sources - emission estimates are provided on an individual plant or emission outlet in conjunction with data on location, capacity or throughput, operating conditions etc.

Area sources - smaller or more diffuse sources of pollution (home heating, public services etc.) are provided on an area basis either for administrative areas, such as counties or municipality, or for regular grids.

Line sources - vehicle emissions from road transport are provided for sections along the line of the road.

8.4.1 Source Sectors

A source sector is a common way of classifying Air Pollution sources and to distinguish emission source sectors, sub-sectors and activities in an inventory. The source sectors are entirely user defined in AirQUIS.

There are several classification systems for source sectors, and each country normally have their own way of grouping the different types of emissions. Two common ways of classifying emission source sectors, sub-sectors and activities are the US-EPA-AP42, (USA) and CORINAIR / SNAP code (Europe).

8.4.2 Emission and consumption data

Data in an emission database could be stored as consumption or emission data. Consumptions data from the various sources together with respective emission factors and source categories are input for calculating emission to air. In the AirQUIS application the fuels and emission factors are entirely user defined.

8.4.2.1 Point Sources

Sources identified on an individual facility basis or as a single source are called point sources. Refineries and industrial plants are examples of point sources. In an inventory conducted at the point/stack level, each stack, vent, or other release points that meet or exceed a specified minimum emission rate should be identified as an emission point. "Point source" emission inventory includes facility identification (industry), location and plant contact, release characteristics for each emission point. Necessary emission parameters for dispersion modelling like location, stack height, stack diameter, gas temperature, and gas exit velocity are also a part the inventory module.

8.4.2.2 Line Sources

Vehicle emission from road transport is handled as line sources.
"Line source" emission inventory include geographical location and static information of each road link, it's dynamic data like annual daily traffic and speed limit, as well as the vehicle distribution for different vehicle classes are defined on each road link.

8.4.2.3 Traffic emission factors

Calculations of emissions from road traffic are based on a set of emission factors consisting of factors for different components for each vehicle classes and fuels. However, the emission factors are not alone enough to describe the emissions, there are several parameters affecting the emissions, like for example traffic speed, road slope and aging vehicle fleet.

8.4.2.4 Area Sources

Area sources are smaller or more diffuse sources of pollution (e.g. small scale industries, home cooking, small combustion sources and open air burning), and are provided on an area basis either for administrative areas, such as counties, municipality etc, or for regular grids. The "Area source" emission inventory includes definition of area source data sets and its emission or consumption values and corresponding emission factors within each defined geographical region or grid cell.

8.4.3 The emission inventory templates

The emission inventory templates (worksheets by MS Excel) are developed by NILU for making bottom – up emission inventory queries. All the Excel sheets are elaborated in a comprehensive way. In the templates help texts and guidelines are given for all type of data to collect. A detailed description of the emission inventory templates is given by Laupsa and Bruno (2004 b).

8.5 Training in Emission inventory data collection performed during the Mission 1

A brief introduction in how to collect and develop a bottom up emission inventory for emission assessment, dispersion modelling, Air Quality Management and planning was given in the workshop. Training in how to use the emission inventory templates exemplified with data from Dhaka was preformed during workshop. A short description of the training is given below:

1. A short demonstration of emission inventory in the Air Quality Management system AirQUIS was given.

2. An introduction to the point source emission template included the following tasks:
   - Presentation of required input data
   - Example of how to prepare an inventory for a brick kiln
   - As an exercise, the participants completed the point emission templates for one new brick kiln
   - The use of the data in an AQMS system (AirQUIS) was demonstrated.

3. An introduction to the line emission templates included the following tasks:
   - Introduction to the required input data
   - Example of how to make a traffic inventory for one road in Dhaka was given.
   - As an exercise the participants completed the traffic emission templates for one road in Dhaka (New Airport Road).
   - The use of data in an AQMS system (AirQUIS) was demonstrated.

4. An introduction to the area emission templates:
   - Introduction to the required input data
   - Example of how to make an area source inventory for one area source (Open air burning of biomass) in Dhaka was given.
   - The use of these data in an AQMS system (AirQUIS) was demonstrated.

All templates (Excel sheets) for making a bottom up emission inventory was given to the AQMP staff at the Department of Environment.

Recommendations on how to start to prepare the emission inventory for Dhaka:

- The AQMP/DoE should contact local and national authorities, organisations and institutions like traffic authorities (Dhaka Transport Coordinating Board) or/and Bangladesh Bureau of Statistics (BBS) to identify if some of the required information for an emission inventory already exists.

- The applied source sectors for Dhaka should be classified according to classifications specified by other authorities in the People's Republic of Bangladesh if available. If no such nomenclature exists for Bangladesh, classification of emission source sectors, sub-sectors and activities should be adopted from other Asian countries, USA (US-EPA, AP42) or Europe (CORINAIR / SNAP code).

- Identify which types of, and which individual sources are responsible for most of the local air emissions of each substance.

- Identify the most important industries and collect required information from these using questionnaires.

9 Task 7: Dispersion Modelling for Dhaka

9.1 Objective

The NILU experts have been asked to assist the AQMP staff in the use of open source dispersion modelling in order to estimate the citywide variation of air pollution levels in Dhaka.

9.2 Status

The staff at DoE/AQMP has never used or been trained in the use of atmospheric dispersion models. Even the use of simple single source dispersion models seems to be unknown to the staff.

During the Mission the NILU experts introduced the AQMP staff to atmospheric dispersion models, and provided them with a simple Gaussian type dispersion model for preliminary impact evaluation for single sources (see Chapter 6 and Appendix C).

To install and operate complete multi-source dispersion models for a large urban area such as Dhaka will be a question of training and long-term collection of input data. The background for these efforts may be described inn the AQMS training programme.

9.3 Actions and future tasks

The **source oriented models** are the type of models requested for Dhaka to be used for air quality assessment and planning purposes. A variety of different models are available on the market today. Their complexity depends strongly on the type of problems, which are to be solved.

Some models are specifically developed and applied for one application only. Very advanced models tend to only become research type models. One should note that it might be a significant step from obtaining a model to actually having an operational modelling tool for a city like Dhaka.

For future modelling in Dhaka it will be necessary to define the objectives and goals. The AirQUIS system provides an urban air pollution model, which has been applied in many cities in Asia, Africa and Europe. It has been designed for planning purposes. Other models may be available through US EPA, such as the Aermod model.

It may be important that the system in Dhaka integrates the emission inventories with the dispersion model so that the total AQMS tools operate on the same GIS based platform.

We have started a process during Mission 1 by providing the AQMP with tools for starting an emission inventory through collecting information and source data. We may well continue to advice AQMP further on how to proceed in order to enable future air pollution modelling and air quality assessment and planning. Also in this part of the development in Dhaka there will be need for a comprehensive training component. The elements of this training were presented in Chapter 7.3.7.

10 Some conclusions from Mission 1

The general impression after Mission 1 in Dhaka is that AQMP need a fair amount of support to start the "road to an Air Quality Management System". The training that has been provided was limited to the operation of a few instruments: The remaining elements of a total air quality assessment and management programme were totally lacking.

A number of instruments have been provided by the World Bank, but the limited amount of training, which have been following these instruments has lead to and will lead to a collection of data (numbers and not concentrations) which can not be used for any air quality assessment or air quality management in the sense of future planning.

The present status of institutional building and knowledge about emission data, modelling and assessment will require that tools and equipment will have to be followed up with a type of training and tools (instruments and databases) that make the total system sustainable. It is thus also important the instruments and data system selected are the same in all parts of the project. It takes time (several years) to establish the knowledge and experience adequate to operate these complex systems.

We have indicated that basic training and introduction to a total air quality management system may be given to the staff at AQMP by NILU in Norway. A proposal for this initial training will be prepared at presented to AQMP.

We have in this report answered to the tasks and obligations outlined in the Terms of Reference from the World Bank. We feel there is still a long way to go. We have given the AQMP staff some tools to start on this road. However, a sustainable air pollution institution in Bangladesh will also depend on decisions made by the authorities to establish a permanent air quality division within DoE.

In the next Mission from the NILU experts we will follow-up on some of these topics, and we will go further in details on QA/QC procedures to improve the quality of the data that is presently being collected. We will also start training the AQMP in receptor modelling. Some filters collected at CAMS by high volume samplers have been brought to NILU for element analyses. However, this will not be sufficient data for performing receptor models.

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Appendix A

People we met

People we met in Dhaka

Govt of the People's Republic of Bangladesh
Office of the Project Director
Air Quality Management Project
Department of Environment
E-16, Agargaon, Sher-e-Bangla Nagar
Dhaka - 1207

From AQMP:

- Dr Mohammed Nasiruddin - Project Director for Air Quality Management Project - DoE
- Ms. Shahana Akhter Deputy Directory Air quality management Project - DoE
- Md. Masud Rana (Senior scientific officer).
- Miss Mitali Parvin (Senior scientific officer)
- Mrs Sabera Nasrin (Senior scientific officer)

Other AQMP Staff:

- Mr. Harun-or-Rashid (Technician, lab)
- Md. Mizanur Rahman (Technician, lab)
- Mr. Masum Billah (Technician, lab)
- Mr. Lutfur Rahman (Technician, lab)
- Mr. Ripon Chandra Sutradhar (Technician, lab)
- Mr. Abdur Rahman (Technician, lab)

From the World Bank

- Dr. Khaliqquzzaman

At Atomic Energy Centre

- Dr Swapan Biswas
- Mm. Bilkis A. Begum

At Norwegian Embassy

- Hans Peter Melby, Counsellor

From NILU

- Bjarne Sivertsen
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Appendix B

Time schedule
Mission 1

Time schedule Mission 1

Based on the tasks identified in the ToR and specified in the Mission 1 proposal, several items will have to be discussed with the AQMP experts. Some of these items are:

- Introductory meeting with a brief introduction to the programme
- AQM approaches
- Background for siting-and list of monitoring stations
- Visit to the sites, discuss representativity
- Evaluate sites, compounds and meteorological data
- QA/QC procedures (calibration, manuals and SOP)
- Data retrieval systems and databases
- Reports and reporting procedures
- Air quality management tools, (assessment and planning?)
- Emission sources (type and locations)
- Emission inventory (methods and status)
- Air pollution dispersion modelling (models and results?)
- Specific industries to be reported (Environmental impact assessment?)
- Brick kilns specifically – what data are available?
- Available training programmes (status and plans)

Based on the introductory discussions detailed schedules for Mission 1 was established.

The schedule is presented in the following table.

Day	Hr.	Assignment	NILU	AQMP/DoE	Done
Mon 16		Travelling via Delhi			
Tue 17	10:00 15:00	Meeting at Dept. of Environment Go through data and reports	BS, HEL BS, HEL	MN, SA, MR	Ok ok
Wed 18	0900 1400	Site visits to monitoring AQ stations Meet with WB: Dr Khaliquzzaman Site representative discussions	BS, HEL BS BS, HEL	SA, MB, LR	Ok ok
Thu 19	0900 1400	Databases and QA/QC system Quality system discussion and reporting	HEL, BS	SA SA + staff	Ok Ok
Fri 20		Day off			
Sat 21	1000	Visit to Brick factory areas, Collect data for assessment-	BS, HEL	MN, SA	Ok
Sun 22		Strike in Bangladesh – No work!			
Mon 23	1000 1500	Seminar AQMS: Emissions, modelling assessment, planning Visits to Atomic Energy, models?	BS, HEL BS, HEL	AQMP staff ++ SA	Ok ok
Tue 24	0930 1200	Visit Norwegian Embassy Training needs assessment – Institutional building Modelling and impact evaluation	BS, HEL BS, HEL	 SA + staff Sa +staff	Ok Ok Ok
Wed 25	0900	Training in collecting emission sources and emission inventories Prepare ToR on Emission Inventory and Final Report	HEL BS	SA + staff	Ok ok
Thu 26	0900 1400	Remaining issues and questions The Chittagong study, planning Final meeting summaries and proposals	BS, HEL	MN, SA MN, SA +staff	Ok Ok

Appendix C

A simple Gaussian dispersion model for point sources

A simple Gaussian Dispersion model for point sources

Introduction

Atmospheric models are, broadly speaking, any mathematical procedure, which results in an estimation of ambient air quality entities (i.e. concentrations, deposition, exceedances).

In general term a distinction between process-oriented models and statistical models can be made. Process oriented models are based on the description of physical/chemical processes: starting with emissions, atmospheric advection and dispersion, chemical transformation and deposition is calculated. This type of models is able to give a description of cause-effect relations. Statistical models are valuable tools in estimating present air quality by means of interpolation and extrapolation of measuring data.

Although atmospheric models are indispensable in air quality assessment studies, their limitations should always be taken into account. Once a model has been developed, the further application of the model will be relatively cheap; however, collecting the necessary input data might be cumbersome. Models can be used for estimating past, present and future air quality, provided that information on emissions is available.

The single source Gaussian type models

The simplest models can be used on personal computers for impact assessment. These models can estimate 1 h average concentration distributions downwind from ground level, diffusive and elevated single sources (Sivertsen 1980, Bøhler 1987).

Gaussian type models are based on Gaussian (normal) probability distribution of the concentration (particle density) in both the vertical and horizontal direction perpendicular to the plume centreline. These models represent simple analytical solutions to the continuity equation, which require homogenous and steady state conditions. The model concept is presented below.

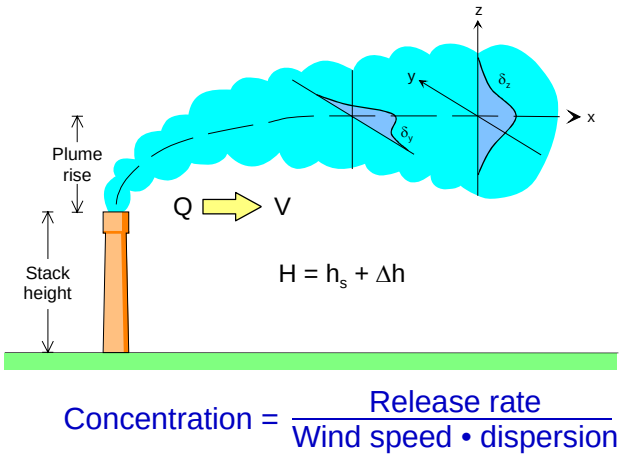

Figure 1: The concept of the Gaussian plume model.

Gaussian type dispersion models are the most commonly applied models in practical use to day. The equation for calculating the concentration (***C***) at ground level, assuming total reflection of the plume at the surface, can be written:

$$C = Q\left[\exp\left(-H^2 / 2\sigma_z^2\right)\cdot\left(-y^2 / 2\sigma_y^2\right)\right] / \left(\pi\sigma_y\sigma_z \cdot u\right)$$

where ***Q*** = release rate (µg/s)
H = effective plume height
σ= dispersion parameters (m)

The co-ordinate y refers to horizontal direction perpendicular to the plume axis, and z is the height above the ground. The ground is assumed to be flat and uniform.

The parameters σ_y and σ_z are the standard deviations of the concentration distribution in y and z directions, respectively. The parameters are usually referred to as the diffusion parameters. The values σ_y and σ_z are functions of the turbulent state of the atmosphere, which again is a function of the mechanical induced turbulence (wind shear, wind profile) and the convective turbulence (temperature profile).

An example of a Gaussian type dispersion model that has been widely used for estimation of impact from single sources and industries is the US-EPA model ISCST2. Also the NILU developed CNCX model is based on the same principles.

The Pasquill stability classes are required as input. Equations that approximately fit the Pasquill-Gifford curves are used to calculate the dispersion parameters in rural mode. In case of urban mode, the dispersion parameters are determined with the expressions of Briggs as reported by Gifford, and which represent a best fit to urban vertical diffusion data reported by McElroy and Pooler. Concentrations can be calculated for a time series of meteorological data (For further reading see: Hanna et.al 1982).

Output from the CONCX model is normally given as ground level concentrations along the centreline as a function of distance from the source.

Model applications
The CONCX type air quality dispersion model have been and are being used for several purposes. Some of the most important areas in which models are of greatest importance are in:

- Existing and future single source impact evaluations
- Siting of large single sources relative to sensitive areas
- Stack height evaluation to avoid adverse impacts
- Estimate the effect of cleaning device
- Evaluate impact of accidental releases
- Area and land use planning purposes

- Planning of measurement programs
- Analysis of measurement data

For the possible impact of SO_2 and PM emissions from a brick kiln located outside Dhaka, the CONCX model was used to estimate downwind concentrations as a function of distance for selected combinations of wind speeds and stabilities of the atmosphere.

Figure 2 shows an example of the calculations performed for a typical brick factory.

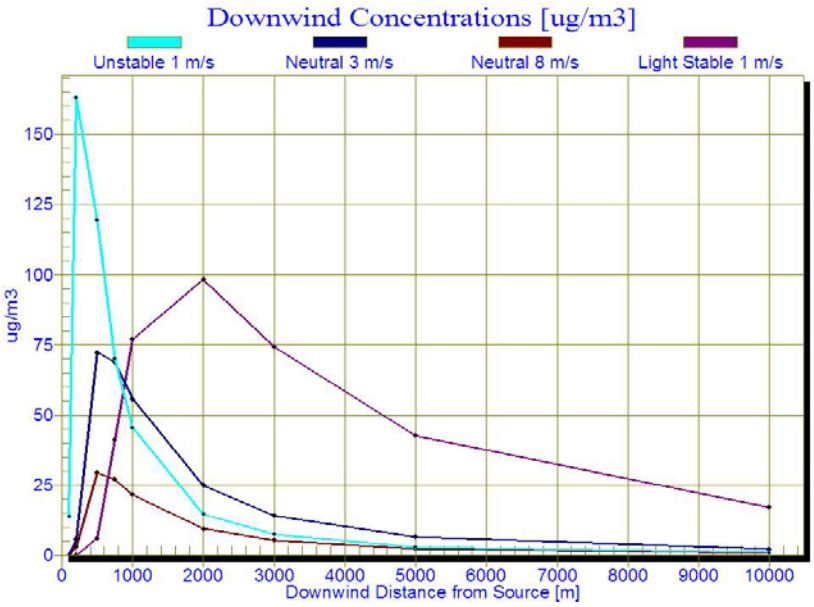

Figure 2: Concentrations of SO_2 estimated downwind from a typical brick factory using the Gaussian type dispersion model CONCX.

Input data

The following information was collected at one of the brick kilns located in the Gabtali area north west of the city centre of Dhaka. In the area there are a total of about 108 brick kilns (stacks).

Fuel used:	Mainly coal (some wood)
Consumption:	about 4 tons/day
Production:	~ 22 000 bricks/day
Sulphur content:	3-4 % S
Ash content:	20-30 %
Stack height:	45 m
Outlet stack diameter:	~ 1 m
Exit gas temperature:	about at ambient

The estimated emission rate of SO_2 is: 3.2 g/s

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Appendix D

Terms of Reference for studies at brick kilns

Terms of Reference

Small studies around industries such as Brick Kilns in Dhaka, The People's Republic of Bangladesh

Background
About 4000 brick kilns are to be found in the surroundings of Dhaka. These brick factories are mostly using Indian coal as feed for the kilns. They are thus expected to emit large amounts of particles and sulphur dioxide into the atmosphere. The Department of Environment wants to study one or a cluster of these factories in order to estimate the possible impact of air pollution on the environment.

The city of Dhaka
Bangladesh is one of the most densely populated countries in the world and its urban areas suffer from air pollution of different levels and it is extremely high in the Dhaka city where the population is about 12 million in 300 km^2 of surface area. It has been estimated that air pollution is causing about 15,000 premature deaths and several million cases of illness every year, in the Dhaka city alone.

The main sources of air pollution in Dhaka is probably linked to road traffic emissions. A number of small industries, brick factories located in the surroundings of Dhaka as well as general activities and open air burning may contribute to the air pollution in the city. Measured levels of PM_{10} and $PM_{2.5}$ frequently exceeds standard values in the winter (dry) season.

Scope of work
1. Identify sources and collect emission data
The first task will be to identify one single or a cluster of brick kilns in the Dhaka area. Then perform an emission inventory for pollutants emitted from these sources.

2. Perform a study of impact at a single source at a multiple of sources
To perform an air pollution impact study at the brick factories will require that the consultant is able to perform the study for a multiple of sources. As a start it may be important to look at the concentration downwind from one single source. However, the emissions and the plumes from these factories, which are located quite close to each other, are so interacting with each other that it will be necessary to see the whole area as a large area of multiple sources.

One way of starting such a study is to perform a kind of screening study using simple measurement equipment. The design of such a study must rely on some simple model estimates as well as information about prevailing wind and dispersion conditions.

3. Perform simple measurements
Plan and undertake measurements downwind from the brick kilns in order to evaluate the relative importance of the emissions from the stacks. Design the exact locations of samplers and instruments.
Take into account all other sources in the surroundings such as trucks and loaders.

4. Estimate impact using models
Based on collected information perform model estimates in order to specify the impact from the brick kilns. Based on the emission estimates use source oriented models to estimate the impacts.

Another method may be to obtain a "fingerprint" of elements and pollutants emitted from the specific factory and then perform multiple element analyses on filters sampled downwind from the industry using e.g. AirMetrics instruments. In this case use receptor oriented models to estimate the relative importance of the brick kilns.

5. Present the results
The results from the investigations should be prepared and submitted in reports as well as presented at a final seminar.

Sustainability
The consultant will provide the tools, extended technical input and provide necessary training to the team at DoE sufficient so that the AQMP staff after completion can continue to undertake similar studies in Dhaka and in Bangladesh.

Appendix E

ToR for Air pollution emission inventory for local air quality assessment in Dhaka

Terms of Reference
Air pollution emission inventory for local air quality assessment in Dhaka, The People's Republic of Bangladesh

Background

The city of Dhaka

Bangladesh is one of the most densely populated countries in the world and its urban areas suffer from air pollution of different levels and it is extremely high in the Dhaka city where the population is about 12 million in 300 km^2 of surface area. It has been estimated that air pollution is causing about 15,000 premature deaths and several million cases of illness every year, in the Dhaka city alone.

The main sources of air pollution in Dhaka is probably linked to road traffic emissions. A number of small industries, brick factories located in the surroundings of Dhaka as well as general activities and open air burning may contribute to the air pollution in the city.

The Air Quality Management Project (AQMP) in Dhaka

The on-going World bank funded Air Quality Management Project (AQMP) operates the air quality measurement stations in the city of Dhaka through the Continuous Air Monitoring Station (CAMS) and stations for 24-hour average samples of PM in the city centre and outskirt of Dhaka. The results of the measurements have shown that $PM_{2.5}$ and PM_{10} concentrations represent the major problem in Dhaka. Traffic is the most important and major source for air pollution in Dhaka, but also other sources like brick factories located in the outskirt of the city, open air burning, small enterprises, and workshops are other sources contributing to the local air pollution level.

Source information needed for air quality assessment

Air quality management and planning requires measurement data of air pollution and meteorology, emission inventories and dispersion models.

To enable the assessment of the air pollution problems, and effectively undertake management and reduction of the air pollution load in the city it will be necessary to have quantitative information about the sources and the amount and types of emitted compounds. Information on pollutant emissions is usually compiled in emission inventories. These are complete and exhaustive lists of emission sources and air pollutants referred to in a specific geographical area and for defined periods of time.

There is presently no local air pollution emission inventory for Dhaka. Investigations have also shown that there is a complete lack of information and overview of the most important emission sources and the location of these. Air pollution emission data have not been collected in Dhaka. As far as information has been made available traffic data and emission factors for Bangladesh is not available. The Department of Environment

(DoE)/AQMP does not have any tools or methods for preparing and utilize an air quality emission inventory.

Objectives
The main objective of the project will be to assist the AQMP/DoE to develop a complete, detailed atmospheric emissions inventory for local air quality in Dhaka, the People's Republic of Bangladesh. The AQMP/DoE staff should be involved in the work to assure a sustainable emission inventory.

The inventory should be one of the bases for air quality assessment, management and planning. A comprehensive inventory should identify which types of, and which individual sources are responsible for most of the local air emissions of each substance. Exact information on source locations and other required information for detailed geographical and time resolution emission and dispersion modelling, such stack height, vehicle distribution and time variation of the emissions, is needed.

Scope of work
The result of the project will represent a complete air pollution emission inventory database including all information relevant for the calculation of emissions of air pollution in Dhaka.

Tools and systems
The consultant should provide tools and methods for collecting the air pollution source data and other relevant information needed to estimate air pollution releases for a number of selected air pollutants. The project also will include tools for easily organizing, storage, analysis and assessment of the air pollution emission data.

Identify sources and sectors
The consultant should assist the staff to identify the most important air pollution sources. The emission sources should be divided into source sectors, sub-sectors and activities in order to classify the air pollution emissions.

The applied source sectors for Dhaka should be classified according to classifications specified by other authorities in the People's Republic of Bangladesh if available.
If no such nomenclature exists for Bangladesh, classification of emission source sectors, sub-sectors and activities should be adopted from other Asian countries, USA (US-EPA, AP42) or Europe (CORINAIR / SNAP code).

Source types (divided into categories)
The emission inventories should in addition divide data into three categories of sources;

- Point sources,
- Area sources and
- Line sources

The different types of sources are treated differently in the atmospheric dispersion models.

Point sources
Sources identified on an individual facility basis or as a single source are defined as point sources. In the inventory, each stack, vent, or other release points that meet or exceed a specified minimum emission rate should be identified as an emission point.

The emission inventory for point source should include includes facility identification, location (co-ordinates of stacks) and release characteristics (consumptions/production and emission factors or direct emissions) for each emission point. Also technical stack parameters such as stack height, stack diameter, exit gas temperature, and exit gas velocity should be collected and stored.

Area sources
Estimates of emissions from small sources, which are not being handled individually such as small scale industries, home cooking, small combustion sources and open air burning should be estimated as area emissions based on unit areas such as small administrative regions, counties, municipalities or regular grids (e.g. square kilometre).

Line sources
Vehicle emissions from road transport provided for sections along the line of the road are normally identified in an emission inventory as road links. The consultant should assist in collection of required information for an emissions inventory regarding the road link network in Dhaka. Typical data and information needed are:
Geographical identification of individual road,
Annual daily traffic density flows
Vehicle distributions (type of vehicles)
Fuel used in different vehicles

Also traffic emission factors should be estimated/ procured/collected for different emission components for each vehicle classes, fuel types and other factors (e.g. speed) affecting the emissions.

Pollutants and indicators
The inventory should provide emission for a number of air pollutants. It is important that the selected compounds are in according to national standards and requirements. The air pollution indicators selected to verify the air quality in Dhaka should be among the selected compounds.

Some of these would be:
- Particles with aerodynamic diameter less than 10 μm (or 2.5 μm), PM_{10} ($PM_{2.5}$),
- Nitrogen dioxide (NO_2),
- Sulphur dioxide (SO_2),
- Carbon monoxide (CO)

Sustainability
The consultant will provide the tools, extended technical input and provide necessary training to the team at DoE sufficient so that the AQMP staff after completion can continue updating the emission inventory in a sustainable way.

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ABSTRACT

NILU experts have been asked by the World Bank to assess and support the Air Quality Assessment work ongoing in Dhaka. This work represents the first Mission of 2 to Dhaka in which the international team provide technical input to the AQMP staff according to the specifications given in the project plan based on the Terms of Reference.

Mr Bjarne Sivertsen and Mrs Herdis Laupsa participated in the first Mission and gave a seminar and a workshop in order to introduce the DoE team to the air quality management systems available internationally. They discussed site selection criteria, performed database assessment, training in emission inventories and simple air pollution modelling as well as assisted in the design of studies for brick kilns.

NORWEGIAN TITLE

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KEYWORDS		
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ABSTRACT (in Norwegian)

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