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How the Scandinavian air pollution research institutes can improve air quality in growing urban spheres in the developing countries

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Contents

1 Introduction

Urban air pollution is becoming an increasing problem in many mega-cities in developing countries. The gravity of the urban air pollution problem is largely attributed to the complex and multi-sectoral nature of everyday air polluting activities as well as the inadequate actions of governments. The lack of actions by governments is further due to poor information and weak understanding of the air pollution problems and, in addition, lack of institutional capacity and coordination among government agencies in the various sectors contributing to air pollution.

Factors such as the high population growth, obsolete industrial technology and the lack of environmental management programmes, give rise to poor air quality, high exposures to the population and following negative health impacts.

One of the main challenges in today's society is to have timely and appropriate access to relevant and good quality environmental data. The aim must be to enable actions whenever environmental requirements and limits are violated. To reduce the impact of air pollution in cities it is necessary to rise the awareness among common people, to educate, train and build institutions that can handle the situation and establish the basis to decision makers in order to take the right actions against air pollution.

I believe that air quality management (AQM) is one key factor in this battle. The air quality management systems (AQMS) is normally expert systems that will have to be established in line with the establishment of expert institutions. In order to develop adequate action plans against air pollution it will be necessary to establish tools that include emission inventories, quality assurance, statistical and numerical models based on advanced computer platforms for data processing, as well as distribution and dissemination of data and model results. Institutional building, training and public awareness will thus represent key elements in the support from Scandinavian research institutions.

The global poverty challenges require that research is actively being used as a policy instrument to stimulate economic growth, sustainable development and enhanced quality of life in the developing countries. Research is vital and useful for formulating an all-embracing policy for the developing countries and is necessary for quality assurance of Scandinavian aid work. As national research centres, the collaborating institutes play an important role in providing research and knowledge to the authorities in support of our international commitment and collaboration with the developing countries.

2 Increasing urbanisation and air pollution

The development of urban areas in developing countries are characterised by a considerable influx of people resulting in slum areas with open air burning and use of bad quality fuels. Also the rapid increase in traffic, using old technology transport means and bad fuels result in emission of particles and gases to the atmosphere.

Air pollution in mega cities around the world has been an issue for several years. At the turn of the century there were 24 mega cities with more than 10 million inhabitants. Four of these had more than 20 million inhabitants in 2002 (UN, 2005). Twelve of the mega cities are located in Asia, four of these cities are in Latin America and two are located in Africa. The African mega cities are presently Cairo in Egypt and Lagos in Nigeria. According to the World Bank some African cities are growing by more than 10% annually, "the highest percentage ever recorded".

Air pollution levels are normally higher in developing countries than in highly developed industrialised countries. The populations of the rapidly expanding large cities of Asia, Africa and Latin America are thus increasingly exposed to levels of ambient air pollution that rival and often exceed those experienced in industrialized countries in the first half of the 20th century (Krzyzanowski and Schwela, 1999).

Activities to manage air quality at the local, regional and national levels need to be integrated to improve air quality in cities. Taking such measures as traffic management or improved urban design at the local level alone may be very cost-effective in reducing the exposure of people living in hot spots, but of limited effectiveness for the protection of society as a whole.

3 Understanding the issue

Air pollution problems are often linked to a combination of emissions and meteorological conditions. In order to understand the background and reasons for air pollution episodes it is necessary to understand the action of wind, turbulence and stabilities of the atmosphere. Emissions of pollutants into the atmosphere have to be identified together with atmosphere's ability to dilute and disperse the pollutants.

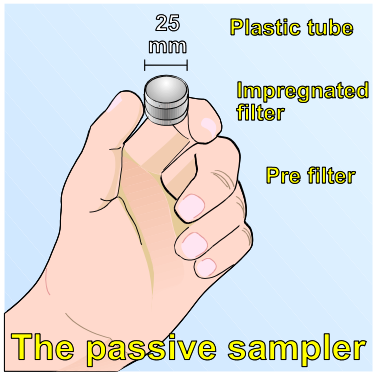
The problems are often evident, but a lack of awareness as well as understanding the consequences leaves the problems unsolved. In order to understand the air quality issues it is necessary for Scandinavian expert institutions to support awareness rising, to build institutions that can follow up and in addition give developing countries adequate economic and technical support.

3.1 Identifying the problem based on screening studies

One tool that can be used in order to identify the problem is to use the Scandinavian developed inexpensive passive samplers to measure a selected number of pollutants in the urban area.

A sensitive diffusion sampler for sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air has been used in several investigations to undertake screening studies of this kind. The samplers are very easy to manufacture. For example, the samplers used by NILU are produced by IVL in Sweden from

commercially available 50 mm long polypropylene tubes. All components, except the impregnated filter can be reused. They have many other advantages, they are small, light (~2 g), and require no electricity.



It should be emphasised that they provide time-integrated concentrations with continuous time coverage, with the averaging time determined by the period they are exposed to ambient air (which can be daily, weekly, monthly, etc.).

A number of screening studies have been undertaken worldwide in order to identify the air pollution problem and to design more advanced monitoring of the air quality. Some examples are given later.

4 Air quality management and planning

To reduce the air pollution exposure in urban areas it is necessary to identify the right actions. This will require appropriate and integrated planning, which in most cases mean that tools and experts will have to be made available.

Supporting air quality management tools to developing countries may give them the ability to improve the air quality. Often the issue of improving the air quality is not only to identify the various actions, but it would be, seen from a decision maker's point of view, important to identify the most cost effective actions.

The main purpose of the Air Quality Management Planning (AQMP) development process is to establish an effective and sound basis for planning and management of air quality in the urban air shed or in selected areas. This type of planning will ensure that significant sources of impacts are identified and controlled in a most cost-effective manner.

The Air Quality Management Planning System includes a number of tasks and steps at all levels of governments. In order to undertake the planning procedures aimed to identify and improve the air quality we have identified the following steps:

1. Air quality goal setting
2. Emission inventories
3. Monitoring
4. Modelling
5. Identification of measures and control options
6. Implementation of the plan
7. Evaluation of changes and impact trends
8. Information to the public

In order to perform the planning process the tools including all the features indicated above is needed. This tool is often referred to as the Air Quality Management System (AQMS), and will be presented in the following.

4.1 The air quality management concept

Optimal abatement strategies were developed by the World Bank for four large urban areas in Asia as early as in 1994-97. Air quality measurements combined with models, dose response functions and effect/cost estimates produced a list of the most cost effective actions that could be implemented in Kathmandu, Mumbai, Jakarta and Manila (Larssen et.al, 1995).

The Urban Air Quality Management Strategy (URBAIR) project was undertaken to assist in the design and implementation of policies, monitoring, and management to restore air quality in Asian metropolitan areas. Its goal was to identify the components of a general action plan to manage and control air pollution. Abatement measures in the plan were categorized according to cost-effectiveness, as well as the time required implementing them and when they would become effective.

As a result of the World Bank project a handbook on air quality management strategy (AQMS) was developed (Shah et.al, 1996) containing the following main components:

- Air quality assessment
- Environmental damage assessment
- Abatement options assessment
- Cost-benefit or cost-effectiveness analyses
- Abatement measures
- Optimum control strategy

Assessment*:* Air quality assessment, environmental damage assessment and abatement options assessment provide input to the cost analysis, which is also based on established air quality objectives (e.g. air quality standards) and economic objectives (e.g. reduction of damage costs). The assessment phase includes collecting air quality and meteorological data as well as emission data and impact and effect assessments.

Abatement : A number of actions may be identified in order to reduce the emissions from different sources. The selection and most cost effective options will strongly depend upon location, the area, topography, and source characteristics. Stakeholders from industries, traffic authorities, and various levels of society will have to participate in this process. Efforts to reduce pollution includes primary regulation (many developing countries have permissive regulations), expanding regulation to new sources, increased fuel efficiency, conversion to cleaner fuels or conversion to electric vehicles with renewable energy sources

Surveillance and institutional building: In order to verify and support the implementation of actions it is necessary to establish a sustainable team of experts, and a information dissemination system. National governments usually assume the responsibility for scientific research and environmental education,

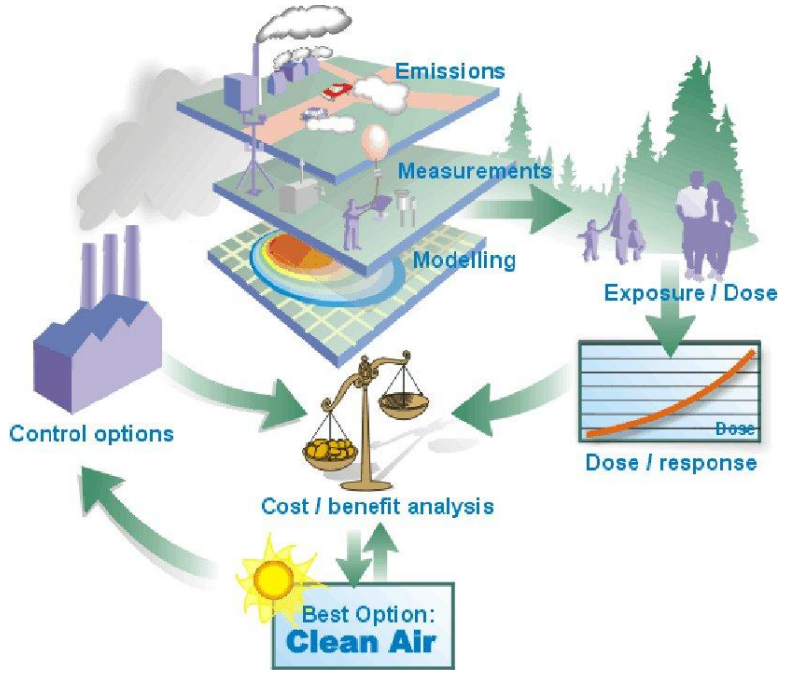
while local governments develop and enforce regulations and policy measures to control local pollution levels. Countries often have their own political and administrative hierarchies and technical expertise that affect institutions, laws and regulations related to air pollution control. It will be necessary to point at the importance of clarity in the organisational structures and the division and description of responsibilities and "lines-of-command".

4.2 The air quality management system (AQMS)

The AQMS depends on the following set of technical and analytical tasks, which can be undertaken by the relevant air quality authorities:

- Creating an inventory of polluting activities and emissions;
- Monitoring air pollution and dispersion parameters;
- Calculating air pollution concentrations with dispersion models;
- Assessing exposure and damage;
- Estimating the effect of abatement and control measures;
- Establishing and improving air pollution regulations and policy measures.

These activities, and the institutions necessary to carry them out, constitute the prerequisites for establishing the AQMS. The elements of the complete integrated AQMS are shown in the Figure below.



The elements of an optimal abatement strategy planning system.

The implementation of plans and strategies for air quality improvements, as performed in some developing countries, is done through the use of policy instruments by ministries, regulatory agencies, law enforcers and other institutions. Indeed, some of these institutions may well be the same institutions as

those, which must be in place to carry out the AQMS analysis described above, which ideally is the basis for the plans and strategies. Thus, the existence of relevant institutions, and an organisational institution structure, is part of the basis for AQMS work.

4.2.1 Air quality monitoring

The monitoring of the air quality is one of the most basic activities in AQM. The AQ monitoring must comply with some basic requirements:

- It is of the utmost importance that the monitoring is done with accepted *standardised methods*.
- The monitored data is subjected to *data quality control* procedures.
- The *location of the monitoring stations* should be based upon some process taking account of locations of main sources, topographical features and meteorological conditions, as well as urban featured and population distribution.
- The monitoring should cover all compounds of relevance in the area, based upon the sources in the area and their emissions of compounds relevant for air pollution and its effects.

The air quality-monitoring network is normally designed to document the concentration levels in the specific area defined by the area description. Indication of source areas, hot spots and adverse impact areas should be part of the initial description. Also air pollution indicators and measurement objectives and strategies have to be presented in the monitoring plan.

4.2.2 The importance of Quality Assurance (QA/QC)

Before air quality data can be used to assess the situation in the area it is important to assure that the data collected are real concentration values, which may be compared to similar information from other areas and countries. For each pollutant, which is measured as input to the air quality assessment and evaluation, the following main questions may be asked:

- Have suitable quality assurance procedures been set up for all stages and activities?
- Is technical advice available?
- Is monitoring being carried out at suitable locations?
- Have suitable arrangements for data handling and storage been made and implemented?

The documentation to support the credibility of data collection and initial data quality assurance are the responsibility of the data provider. This includes the process of data collection, application of calibration factors, initial Quality Assurance procedures (QA/QC), data analysis, data "flagging", rollups (averaging) and reporting. A combination of data record notes, data quality flags and process documentation are all part of this first phase of processing. During the data collection phase, one role of the data provider is to assist in maintaining process credibility and validity of the data.

4.2.3 Emission inventories

The emission inventory, which is another important part of the input data for air quality management planning, starts with identifying all relevant sources in the area. For each source that may emit air pollution of interest, which may create air pollution problems and contribute to the exposure of air pollution data must be collected on:

- Type of source; industry, mobile, domestic etc.
- Location
- Amount of emission
- Variation of the emissions with time (hour, day, day, week and year).

The information of sources should be presented on GIS maps of the area. The output, after estimation of emission rates, is total and spatially distributed emission amounts. The emission distribution provides input to the dispersion models for calculating air pollution concentrations in the area by time and location. It also provides a basis for calculating the effects of various specific abatement measures on air quality.

There may also be a need for using simplified tools for emission inventorying along with some simpler methods for a fist evaluation of the problem. Some of these methods have been applied in developing countries as a first approach in order to evaluate the relative importance of different sources (Sivertsen and Dudek, 2007).

4.2.4 Air quality modelling

Air quality modelling seeks to combine knowledge of pollutant source strengths (i.e. emitted quantities per unit time) with meteorological data to estimate concentrations at the receptor points. Models have varying degrees of sophistication and accuracy and are rarely better than plus or minus 20-30 percent of the “actual value”, unless the model is "tuned" by use of pollution monitoring data (stochastic modelling).

To obtain the theoretical background and the practical application of models is a major challenge in developing countries. The need for training in this field goes back to basic scientific knowledge and teaching at a university level. Most often experts will have to be selected with sound background in geophysics or meteorology or related topics. For scientific institutions in Scandinavia the challenge is often to bring coming experts to Scandinavia for one year training or Master/PhD degrees.

5 Examples of AQM planning projects

Some of the programmes undertaken in order to support developing countries in improving their air quality is presented in the following. The projects may divided into:

1. Evaluation of existing programmes
2. Screening studies to identify the problem

3. Road map for further development
4. Support design and establish monitoring and management programme
5. Support development of action plans
6. Awareness rising – web solutions
7. Training and institutional building

Brief descriptions are presented in the following.

5.1 Evaluation of existing programmes

NILU has been asked by the World Bank to evaluate existing AQM programmes with the objective of identifying the present data quality and assess the use of the information for air quality planning.
On example is from Bangladesh where the programme included:

- ✓ Sites and instruments
- ✓ Representativity
- ✓ Quality Assurance
- ✓ Data retrieval and databases
- ✓ Assessment and reporting
- ✓ Applicability for planning

5.2 Screening studies to identify the problem

Screening studies and indicative measurements may be implemented as an assessment method in order to assess the present level of air pollution. Indicative measurement techniques based on the use of mobile stations and manual measurement methods, such as the diffusive sampling technique, are of particular interest, because of their relatively low cost and their simple operation in comparison with fixed monitoring stations.

NILU performed several studies of this kind in order to identify whether advanced measurements are needed. In Cairo, Dakar, Durban and Hochiminh City these studies were undertaken to identify locations for more advanced measurements. In Zambia the main objectives was to establish basic knowledge about possible impact of SO_2. Simple inexpensive passive samplers were used and supplemented by simple air pollution dispersion calculations.

5.3 Road map for further development

On request from the World Bank NILU proposed a road map for the development of an integrated air quality monitoring programme for Hanoi. Some of the instruments already operated in the city may have reached the end of their lifetime. Some instruments may be used in the future programme, but there was also identified a need to upgrade and install new stations.

This approach will be better than trying to repair something that will never work. All data should be transferred to one central database system. It had become evident that there might be a long way to go to achieve a modern internationally recognised air quality monitoring system. The fact that there are already four

operators and four different systems in Hanoi has also represented a complicating factor.

The World Bank/NILU staffs has specified some critical success factors for the implementation of the specified road map, including:

- Training for operating and maintaining of the instruments
- Similar data loggers and data retrieval systems
- A central data base with QA/QC procedures
- Annual budgets for consumables and spare parts
- Upgrade the QA/QC system and perform training and follow-up
- Training in understanding Air Quality Management
- Collect source information and develop emission inventory

5.4 Support design and establish monitoring and management programme

In a number of projects around the world NILU supported local institutions and experts to design and establish air quality monitoring programmes aimed to give input to the air quality planning process.

The design of a monitoring programme has to clearly state the objectives of the measurements. One general objective for the air quality measurement programme could be to adequately characterise air pollution for the city with a minimum expenditure of time and money. The measurement and sampling techniques to be used will be dependent upon a complete analysis of the problem (emission source, dispersion conditions and the current air pollution situation).

For studies like the one NILU performed in cities like Hanoi, Dakar, Durban, Cairo, Yantai and others the objectives would be to verify the current levels of pollution relative to limit values, to estimate importance of different sources, to verify trends and effects of actions to reduce pollution and to develop abatement strategies.

To meet these objectives the city will need a permanent network of stations covering different microenvironments of the city. It is also important to carefully characterise the monitoring representativeness, and to specify what kind of stations we are reporting data from.

5.5 Support development of action plans

NILU supported the development of action plans for air quality improvement in several cities. Following the installation of AQMS, training of experts, development of air quality monitoring programmes and preparation of input data for modelling the following main tasks were undertaken:

- Air Quality Assessment
- Health impacts analyses and evaluation
- Identification of abatement options
- Cost/effectiveness analyses or cost/benefit analyses

- Optimal abatement strategy plan development

In order to arrive at the most advances basis for the prioritised action plan 6 steps will have to be followed:

1 Identify the population and stock/assets at risk due to pollution

The population-at-risk may be all the residents of a polluted area, or a fraction thereof, such as elderly people or people with a chronic respiratory affection. The stock-at-risk refers to the area exposed steel or zinc, or the area of wheat or rice in the impacted area.

2. ***Determine the number of people and objects that are exposed to ambient pollution that exceeds standards or guidelines.***

This provides a first indication of the extent of benefits/damages. The amount by which standards are exceeded provides additional information on possible health impacts.

3. Identify relevant dose-response functions

Relate ambient levels of pollutants to impacts on specific assets or certain aspects of health. For many pollutants, the severity of health impacts is directly correlated to the concentration of pollutants. Different levels of pollutant concentrations result in differing degrees of symptoms.

4. Calculate marginal physical impact

Multiply the population-at-risk and/or the stock-at-risk with the impact per unit of pollution in the reference scenario.

5. Determine monetary values per unit of physical impact

Estimate unit costs depending on the type of impact. Impacts on productive processes (e.g. crop production) can be valued with market prices. Health and ecological impacts and those on nature cannot be directly valued with market prices.

6. Calculate the monetary value of benefits/damage

Estimate the value of exposure reduction due to change in air pollution by multiplying marginal physical impact (4) with the monetary unit values (5).

5.6 Awareness rising – web solutions

Different tools could be made available for raising the awareness of air pollution among public, stakeholders, decision makers and politicians:

- Media campaigns in the press, on radio, television, bill boards;
- Public seminars and workshops;
- Distribution of leaflets;
- Effective education programmes developed for primary and secondary schools taking into account the local context;
- The organisation of clean air events to coincide with recognised events such as World Environment Day; and
- Maintenance of an informative and up-to-date website.

The dissemination channels likely to be used are in addition to Internet over the next years is WAP, e-mail and SMS, to be combined with subscription services for personalised information.

Web-portals have been established showing on-line air quality data as well as historical air quality data and emissions. Status of air quality compared to standards and guidelines is also displayed. Functionality to include written reports may also be provided. The best Internet pages includes in addition to on-line information general information about air pollution and its effects on humans and nature.

In order to simplify the information to the public many countries and urban areas in Asia have adapted Air Quality Index (AQI) values. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy.

The purpose of the AQI is to help the user to understand what local air quality means to the health. In order to make the AQI as easy to understand as possible, the AQI values have been divided into six categories, often presented to the public as a colour code as shown below:

Each category corresponds to a different level of health concern. For example, when the AQI for a pollutant is between 51 and 100, the health concern is "Moderate." In Hochiminh City the data provided from the network of 9 stations are merged into two AQI values; one for streets and roads and one for the urban background concentrations. These values are displayed on a daily basis on a large billboard in the city centre as well as on the home page of HCMC Environmental Protection Agency.

Air Quality Index (AQI) Values	**Levels of Health Concern**	**Colours**
When the AQI is in this range:	***...air quality conditions are:***	***...as symbolized by this color:***
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Typical AQI scaling from good air quality to hazardous air quality.

5.7 Training and institutional building

As part of the establishment of air quality planning procedures in urban areas of the developing countries there will be a need to perform capacity building to individuals, institutions and decision makers.

The complete integrated AQMS has to be considered an expert system. For this reason there will always be a need for training and capacity building throughout the different levels of the air quality organisations. The limitations in the developing countries concerning the identification of Cost effective abatement strategies and Action plans is the availability of trained experts. One goal should thus be to establish institutions that can handle the integrated AQM systems.

This will require basic institutional building in addition to the training of operation of the monitoring and management system. Capacity building and training should be combined through seminars, workshops and on the job training. General institutional strengthening through air quality lectures and seminars should be organised using the available expertise at national universities as well as international experts.

One of the most important input from Scandinavian research institutes may therefore be to provide assistance to the project partners during the initial phase of the air quality management planning process at different levels of the organisations in the development country.

6 Summary

In summary I believe that the development and training in the use of an air quality management system is one key factor in the battle for cleaner air in urban areas of the developing world.

Institutional building, training and public awareness will represent key elements in the support from Scandinavian research institutions. Also simple inexpensive instrument packages for identifying the problem through simple screening programmes will be an important part of the process towards cleaner air.

Some simpler tools; such as top-down emission inventories combined with simple models may be applied in a first phase in order to roughly estimate the importance of different sources.

In the long run, however, I believe that the development of a complete integrated planning tool will provide the training needed in order to establish expert institutions. It will also be the only way to actually quantify in a proper way the most cost effective actions to be implemented in order to reach the goal of a cleaner environment.

The starting point for all these processes is the terminology presented in the DPSIR framework.

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