Evolution of Air Pollution Monitoring From a System for Experts to an Individual Source of Information for Everybody

Besides remote transport of pollutants, air pollution is caused by a multitude of local temporally fluctuating sources. The knowledge of the current pollution situation on a small scale is necessary for people´s health protection. To meet this requirement and considering the capability of micro-scale models, a higher number of measuring stations with intelligent concepts have to be set up. There is a trend towards miniaturisation of measuring stations comparable to that of computer technology or mobile phones. With these new developments and their energy-saving operation, a cost reduction without loss of data quality is achieved [1]. Future developments will focus on further miniaturisation by using alternative sensor technologies and the application of the measurement as a tool not only for recording, but also for the forecast of air quality.

1. Initial Situation

Besides economic, the ecological quality of life plays a more and more important role. This has become apparent by an increasing consumption of organic products, reinforced non-smoker protection and an increasing general health awareness.

Individuals can decide how they live, where they stay and what they eat and drink. While quality of food and water can be monitored fairly well, monitoring breathable air is more difficult.

Who of us actually does not think about the air being emitted from a car exhaust pipe or the cloud of solvents or the current dust exposure caused by a building site as being harmful to our health?

Preferably, air quality monitoring should indicate the exposure of population to pollutants. Health protection is the actual task of monitoring.

This task can only be fulfilled sufficiently if the exposure to pollutants is known at the respective location of the population. For this purpose, monitoring has to be done particularly in urban areas with high areal density and at spots with high pollutant concentrations caused by local sources. Air quality is not only a regional but a dynamic and local parameter as well.

2. Stage of Development and Resulting Problem Statement

"My method is my castle - this is...still the way how to describe the mood of many natural scientists and technicians" Peter Bruckmann [2] wrote in an article in May 2002 and complains about the unreadiness of the participating scientists to adjust to new concepts in air quality monitoring. The structure of existing air quality monitoring networks does not allow for the "local factor" due to the fact that they are not designed for such tasks [2].

Present monitoring stations are self-acting laboratories with cyclic data requests. Based on the differences of the individual measuring principles each pollutant is monitored with an analyser of its own. Each instrument is the size of a small case, weighs about 10 to 20 kg and has to be operated in an air-conditioned environment. The instruments feature the German Eignungsprüfung (a performance test) and based upon the EU or US EPA reference method. The analysers are mounted in an instrument cabinet inside a container approximately the size of a building site container. Calibration equipment, control box, air conditioning, standardised sampling system and data acquisition device complete a traditional measuring station for air quality monitoring.

The stations are therefore large and take a lot of effort to install and operate. In addition to their high power consumption, the measuring site is often determined by feasibility rather than by an installation site useful for the measurement. Even the moving of these stations to sites of an increasing interest of measurement target is difficult to achieve.

Data recorded thereby reproduce more large-scale fluctuations of the pollutant concentration determined by meteorological parameters than the pollutant dose man and nature are exposed to on the spot. Local and sporadic sources may not be considered by the traditional concept. Notwithstanding that they are most of all significant when occuring at spots with a momentary high number of people (e.g. bus stops, traffic jams, building sites). To decrease the discrepancy between the measurement and the pollutant dose inhaled by the population, an improved measure concept has to comply with these "local" requirements.

3. Approaches

3.1. Modeling

Recent developments demonstrate opportunities for a small-scale modeling [3] with entering the background level, meteorologic parameters, building-density, type of traffic, its density and other sources as input parameters.

Such a procedure is for example applied in North Rhine-Westphalia [4]. An online program version enables cities and communities to accomplish the identification of potential pollution focuses with limit value violations. Naturally, these models show a high dependency on the quality and the amount of input data being used. Data can only express what is provided by the quality of input data. Building sites and varying traffic density remain unconsidered. Small-scale modelings can only partially reproduce the local air quality due to not considering varying concentrations caused by local events. The model quality could be improved by combining modeling and small-scale measurements.

3.2. Passive Samplers

The most simple measuring methods such as passive samplers are often used with acquisition of nitrogen dioxide and hydrocarbon concentration. They show a simple design, operate without power consumption and are very cheap.

Diffusion tubes are analysed in a laboratory after a defined sampling period. Due to the dependence between sampling efficiency, ambient temperature and relative humidity on one hand, and the significant proportion of manual sample handling on the other, deviations from the actual pollutant concentration might occur. Furthermore, it is disadvantageous that passive samplers allow only for inferences on past expositions. Only results integrated for the measurement period can be captured, but not peak loads. Besides, not all relevant airborne pollutants can be detected with this method.

3.3. Miniaturisation

Often the installation of a traditional measuring station with its necessary setup (telephone connection, power supply, foundation) is impossible. For meeting these obstacles, the measurement technique being used has to be small-scaled and simple to operate.

3.3.1. Alternative Sensor Technologies

Apart from the reference procedure there are further measuring principles for capturing the relevant airborne pollutants, for example electrochemical or semiconductor sensors. These methods are successfully used with industrial hygiene and occupational health protection. Due to their compact design, low production and low maintenance costs they are appropriate for use in compact systems. Such systems for "Hot Spot" monitoring already exist.

On closer examination it becomes clear that these procedures do not allow for a reliable measurement at the moment. The sensors are either not sensitive enough, unstable, or cannot be calibrated. Furthermore, significant interferences do frequently occur. The comparability of results with the reference method is not given.

3.3.2. Small-Sized Measuring Station

The procedures presented in the preceeding paragraphs are only in a limited way suitable for a reliable and prompt capture of the exposure situation at centers of pollutant concentrations. With the pressure for capturing such data being high, it is attempted to minimise the traditional measuring stations to enable an installation even at spots, where conventional measurement techniques are not applicable.

Instruments in these traffic measuring stations are identical to those of traditional measuring stations, however they only use the instruments required thus saving space. Some small-sized measuring stations only provide the installation of a few instruments relevant for the respective measurement (e.g. NO_x, PM10). Otherwise the basic setup does not differ from a conventional measuring station. Sampling system, air conditioning and data logging are comparable. This kind of station is available as a portable or stationary unit. The smallest possible dimensions come to 2m x 1m x 2m (DxWxH) for the portable station and 0.9m x 0.6m x 1.5 m (DxWxH) for the fixed station.

These stations can also be provided with advanced wireless data acquisition systems. A 230V power supply is sufficient despite internal air conditioning. Therefore, substantial hurdles preventing installation of the station for monitoring road traffic do not apply.

However in many cases even these stations are too large or too expensive to install with the necessary areal density under operating conditions.

3.3.3. airpointer®

To identify hot spots and to obtain a comprehensive survey of the respective air quality the measuring method has to fulfill the following requirements:

- Fast (indication of short-term fluctuations)
- Current (information of the population)
- Accuracy (precision, interferences)
- Cost-effective (purchase and operation)
- Light (easy to install)
- Small (measuring site determined by application)
- Flexible (adjustable to application).

Figure 1: airpointer® compared to a traditional measuring station on the occasion of the Steyregg round robin test [1]

Miniaturised and integrated measuring stations like the airpointer® are an important step in the development of measurement technique.

Significant measurements even for short-term peaks are possible by continuous sensors being used. Due to the data being provided on the Internet, the population can be informed immediately. All other sources of information can be used as well.

By the EU reference methods used for the most important gaseous components SO_2, $NO/NO_2/NO_x$, ozone and CO regulated by law, the requirements of the respective EN regulations are exceeded. Further sensors can be integrated into the airpointer® as well. Compared to conventional measuring stations, not only the investment costs but also the follow-up costs are insignificant due to little power consumption and maintenance requirements.

Installation can be accomplished everywhere, even in road traffic. With the low power consumption and data transfer on the Internet only a normal power supply (e.g. a lamp post) needs to be available on site. Internal sensors can easily be refitted to the required air pollutants on site. A low power consumption is accomplished by a most compact design and intelligent temperature management.

With this in mind, the airpointer® annually saves more than €4.000 of energy costs compared to a conventional measuring station while securing consistent data quality. Besides data transfer, even quality assurance and the complete operation of the instrument can be accomplished locally or remotely controlled on the Internet. Besides accessing certain displays, web pages can be updated with latest measurement data automatically and permanently for means of public information. The standardised output helps realising the integration of airpointer® data into existing monitoring networks.

The airpointer® allows for measurements in accordance with EU legislation at spots so far inaccessible or at least difficult to access including crossroads and urban canyons, tunnels, traffic jam areas, pedestrian zones, schools, factories, ships and building sites.

4. Outlook

4.1. Future Development of Measurement Technique

In the near future, the miniaturisation of the emission measurement systems will advance further to provide more and more cost-effective measurements.

One cannot help thinking of the comparison with the development in computer technology. The first computers (IBM etc.) filled an entire room in a building. The next generation (PDP-11 from DEC etc.) in the eighties was the size of an office cabinet. At that time, the first monitoring analysers based on physical principles came into the market with an analog technique. The PC marked the breakthrough in the professional use of the computer.

The applied analytic modules show a definite tendency towards miniaturisation. Compared to the first analysers based on today´s measuring principles, the internal volume has been reduced and the internal tube diameters have become smaller, assemblies combined and standardised. An end of this trend is not foreseeable, especially because alternative sensor technologies and multi-component sensors could become accepted in the future, i.e. as soon as they will be able to provide a comparable detection limit and selectivity.

Figure 2: airpointer® in use

4.2. Forecast

Many current methods such as the reference methods for PM measurements or the collection of pollutants by passive samplers consist of a measurement, the sample transported to a laboratory, and the subsequent analysis. This method shows the basic disadvantage that data is only available after a fairly long time. With high pollutant concentrations, society can not be informed immediately. Therefore, these methods are suited more for data acquisition than for direct health protection.

Displaying online measurement data using continuous methods is the current technique used. Current warnings can be issued by means of this method allowing sensitive people to protect themselves against exposure (PM10, NO_2, ozone).

Comparing this method with those used in meteorology leads to the following conclusions:

A weather record history is essential for subsequent data processing. It is irrelevant, whether the data was obtained by continuous methods or in a laboratory. Long-term conclusions can be drawn and measures derived by the obtained data, which are of interest especially for science and research. This procedure corresponds to the main purpose of the Federal States´ monitoring networks.

On the other hand, the current weather conditions are of interest to a larger group of people.

Currently pollution data is automatically published on the Internet or teletext by monitoring networks. However, having been designed for data acquisition, monitoring networks do not deal with small-scale exposure in congested areas.

In meteorology, the weather forecast is the main public interest. Future developments are pre-estimated by means of weather models.

The essential parameters are identical to those of the development of the emission situation, therefore models are already used in emission to forecast large-scale exposures [5]. In the future, the health-conscious part of the population will increasingly pay attention to the air quality which they are breathing and plan their activities accordingly. For this purpose, a forecast of pollution development is necessary which should not be interpretable by an expert only, but should be prepared in a comprehensible way and to be easily understood by the public in general.

With various sources emitting pollutants most notably in urban areas, the local variability of air quality is considerably larger than that of the weather. New methods should enable a small-scale emission forecast based on measurements with locally collected data.

Then, preventive reduction measures for population protection can be taken at short notice.

The combination with mobile radio cells, that are prevalent especially in populated areas, would also allow comprehensive local prognosis.

[1] Danninger, E.: Bericht über den 3. Österreichischen Feldringversuch für Luftschadstoffe in Steyregg 8.10.2007 bis 12.10.2007, http://www.land-oberoesterreich.gv.at/cps/rde/xbcr/SID-31947698-26B29207/ooe/Feldringversuch2007.pdf

[2] Bruckmann, P.: Luftreinhalter aller Disziplinen vereinigt euch!, Gefahrst.-Reinh. der Luft (Mai 2002)

[3] Diegmann, V., Annecke, R., Mahlau, A.: Echtzeit-Screening-System zur stadtweiten Berechnung der Schadstoff- und Lärmbelastung auf Basis von Verkehrsdaten; In: Strobl/Blaschke/Griesebner (Hrsg.): Angewandte Geoinformatik 2004, Wichmann Verlag Heidelberg, S. 85-89

[4] http://www.lanuv.nrw.de/luft/ausbreitung/luft_screening.htm

[5] http://db.eurad.uni-koeln.de/index.html?/prognose/

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