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COMPLEX AIR QUALITY MANAGEMENT SYSTEM IN A LARGE CITY: EXAMPLE OF RIGA CITY, LATVIA

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ABSTRACT

Complex air quality (AQ) management system consists of a number of elements which could be divided into 4 main functional blocks: 1) Data and information generation and gathering; 2) Assessment, reporting and dissemination of information; 3) Decision making and public involvement; 4) Implementation of actions. Environmental monitoring is the main tool for data and information generation. Besides, AQ modelling plays more and more important role.
Riga is the biggest city in the country (~764 thousands or 32 % of Latvia's total population) with intensive traffic and economic activities. It is the only one agglomeration with respect to AQ management nominated in Latvia.
Until 1997 AQ monitoring in Riga was based on manual methods. Since 1998 the core of observation system is based on automatic measuring devices mainly employing the method of differential optical absorption spectroscopy (DOAS). In 2005 the eight stations are representing different institutional systems of AQ monitoring – state (3), municipal (3) and enterprise (2). All of them are technically and methodologically (data quality assurance and control) maintained by Latvian Environment, Geology and Meteorology Agency (LEGMA). More separated are information dissemination patterns including on-line access to information published on Internet homepages both of LEGMA and Riga municipality.
AQ problems in Riga are represented by elevated concentrations of NO_2, PM_{10} and benzene. All responsibility for improvement of AQ in Riga is delegated to Riga City Council. Action plan on improvement of AQ in Riga City has been approved in 2004 comprising actions to be carried out until 2009.

Key Words: Air Quality, Air Quality Management System, Riga, Latvia

1. INTRODUCTION

Atmosphere air is one of the most important environmental factors influencing human health. Especially the problems of air quality (AQ) are emerging in large cities and industrial zones.
Latvia during the preparation process to join the European Union (EU) began to incorporate EU requirements for ambient AQ monitoring and related AQ standards into the environmental legislation of Latvia since late 1990-ties, several years before official status of an EU member state from May 1, 2004. These AQ standards and monitoring pattern substantially differs from the previous one implemented during Soviet times and in the first half of 1990-ties after regaining of independence in 1991 (Table 1).

Table 1. Comparison of two AQ standard's, monitoring and legislation systems

System implemented in the former Soviet Union	System implemented in the European Union
Many polluting substances	Prioritized polluting substances
AQ standards in the form of Maximum Permissible Concentration in relation to instantaneously measured and daily averaged concentrations	Broad range of limit values from one-hour to mean annual concentration
Discrete manual sampling	Continuous automated measurements
Quite inflexible monitoring	Flexible monitoring based on amount of population exposed and actual AQ situation
Minimum monitoring requirements not specified	Minimum monitoring requirements specified

Complex AQ management system consists of a number of elements which could be divided into 4 main functional blocks: 1) Data and information generation and gathering; 2) Assessment, reporting and dissemination of information; 3) Decision making and public involvement; 4) Implementation of actions. Accordingly, proper AQ information system is the basic prerequisite for management of AQ. The main elements of the environmental information system are data gathering patterns (monitoring, scientific investigations, statistics, modeling), data processing and storage and reporting (operationally, monthly, annually, etc.) to decision makers and public (Fig. 1).

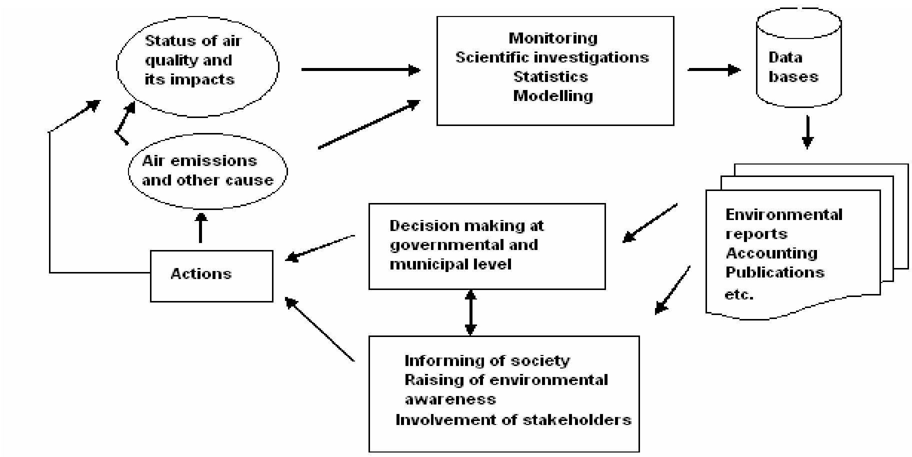

Figure 1. Conceptual AQ management system (Kadikis et al., 2002).

Environmental monitoring plays the key role in supplying environmental information. Besides, AQ modeling plays more and more important role in providing additional information on AQ status.
The paper aims at development of general principles and possible solutions for complex AQ management system in a large city, irrespective of its geographical

location reflecting the development of AQ management system in Riga City, the capital of Latvia.

2. MAIN TEXT

2.1. Brief characterization of Riga City

Riga is the capital of Latvia and the largest city of the Baltic States. It is located on the plain area on the southern shores of the Baltic Sea at the mouth of the Daugava River. The city's crossroads location between Western Europe and huge Eastern markets is one of Riga's attractions for business activities. This favorable location and membership in the Hanseatic League of northern cities has promoted the rapid development of the city since it’s founding in 1201.

According to data from the last population census in 2000, Riga has the population of ~764 thousands (~32 % of Latvia’s total population) and intensive traffic and economic activities, as well. The maximum number of inhabitants was reached in 1990 – ~ 912 thousands owing to mechanical migration from other parts of former Soviet Union.

Territory of Riga City occupies ~ 307 km^2. 5,7 % cover streets and highways, 5,2 % - industrial areas, 4,3 % - technical services zones (railway, power stations, garages, etc.), 1,7 % - port areas. Nature and greenery takes up of 36,6 % of city territory (CEROI, 2004). It consists of nature areas, nature protection zones, various forms of greenery - parks, gardens, etc. The street and arterial road network in the central part of Riga was developed at least 150 years ago and is not able to accommodate today's increasing traffic.

Riga’s climate is determined by prevailing air masses from the Atlantic Ocean. This maritime influence results in mild winters and cool summers as well as high air humidity (80%). Average long period temperature is - 4.9 ^oC in January and + 16.9 ^oC in July. The air temperature is usually 2-3 ^{o} C higher in the center of Riga than in the suburbs. Snow cover during winter is normally sustained for a short period. Autumn is the windiest season but windy days are occurring quite often through the year favoring air circulation.

2.2. History and development of AQ monitoring in Riga

The first AQ assessment performed in Riga dates back to 1913. Regular AQ observations in Riga as pilot observations started in 1965, being the first AQ monitoring observations in Latvia. Permanent observation’s program in Riga was launched in 1969 and until 1974 steady AQ monitoring in Latvia was carried out only in Riga covering 3 posts. Total number of AQ monitoring sites within the state monitoring system reached 5 posts until 1997 selected as a frontier zone between industrial and residential areas and in the central part of the city influenced by traffic. The monitoring was based on manual sampling methods (3-4 times per day for SO_2, NO_2, TSP[1], CO, NH_3, phenol, etc. and 1 time per month for Cd, Cu, Pb, Zn in TSP) followed by conventional laboratory analyses and, therefore, often called as wet

[1] Total suspended particulates

chemistry methods. Before regaining of independence in 1991, observation's network of Latvia was included in the state observational network of the former Soviet Union and unified methods were implemented summarized in the Guidance on control on atmosphere pollution (Anonymous, 1991).

The turning point in the development of state AQ monitoring system in Latvia relates to introduction of automated, continuous measurements performed by means of instruments implying differential optical absorption spectroscopy (DOAS) method. Devices based on DOAS method consist of light emitter and receiver, which are placed at some distance (up to few 100 m) and, therefore, measure average concentration of air pollutants within the particular spatial distance. To some extent, the reason for such preference to choose DOAS equipment as a basic element of state AQ monitoring system was the previously got experience from the first DOAS station operating within municipal observational network in Riga since 1994. On the other hand, DOAS technique seemed to provide advanced and modern opportunities in development of automated AQ monitoring equipment (Leitass, 2000). From 1998 to 2002 the amount of DOAS stations (produced by OPSIS AB, Sweden) operating within the framework of state monitoring network in Riga reached 4 stations (totally, in Latvia operated 13 stations) supplemented by 1 municipal observation station. The standard set of parameters included SO_2, NO_2, O_3, benzene, toluene, and xylenes. Additionally, formaldehyde was determined at one station.

Several other important parameters required by European directives, namely, CO and PM_{10} particulate matter are detected on continuously basis applying different from DOAS techniques - infrared spectrophotometer for measurements of CO and beta ray attenuation method for detection of PM_{10}. Additionally Hg fumes were detected by means of atomic absorption mercury vapor analyzer. In their turn, the combusted PM_{10} samples are used for laboratory analyses on heavy metals (Zn, Cu, Cd, Pb, Ni, As, Mn) with atomic absorption flame spectrophotometer.

Remarkable changes in observational programme occurred in 2003 as two new automatic municipal stations (DOAS station and a "single point" station based on gas chromatography principles and produced by HORIBA, Germany) have been installed in Riga. Since 2004 two DOAS installations are located in the territory of Riga Commercial Free Port responding to rising public concerns about air pollution caused by harbor operations. The mentioned stations are financially maintained by the enterprise itself and provide example of enterprise AQ monitoring.

Summary on main development stages of AQ monitoring in Riga is given in the table 2.

Besides, new possibilities for air quality monitoring have been provided with the development of diffusive sampling methods being some advanced derivation of wet chemistry methods as conventional laboratory analyses are involved. Usually diffusive samplers are placed in smaller towns, which is not possible to equip with expensive automated analyzers or in order to gather additional information on AQ with regard to more detailed distribution of polluting substances. A short time measurement campaign of NO_2 and benzene pollution in Riga was performed in 2003 using diffusive samplers.

As regards 2005, there are 8 automated monitoring stations operating in Riga and representing different institutional framework (Fig. 2, Table 3). 7 of them are DOAS stations and 1 is "point" station, which is based on gas chromatography (street

Valdemāra). Additional analyzers determining a number of supplementary pollutants equip some of the stations. 5 stations belong to Latvian Environment, Geology and Meteorology Agency (LEGMA) – a state agency under the Ministry of Environment. The agency is the main authority responsible for AQ monitoring and assessment in Latvia having skilled technical staff and specialists capable to carry out technical maintenance of monitoring stations and data quality assurance / quality control (QA/QC) (Kadikis et al., 2004). Despite 3 other stations are the property of Riga municipality, technical maintenance as well as data QA/QC is done by LEGMA on contract basis. The same general principles with respect to technical maintenance and QA/QC apply to stations that have been rented to Riga Commercial Free Port and are working at industrial sites. So, neither municipality, nor enterprise is obliged to maintain its own staff capable to ensure reliable measurements within municipal or industrial monitoring network. It should be mentioned that LEGMA is accredited according to EN ISO 9001:2000 standard (introduction of overall quality management system in all operations performed by the agency) since 2004.

Table 2. Summary on AQ monitoring in Riga, 1969 – 2005

Manual methods			Continuous automated methods			
Pollutants	Maximum number of stations sampled during one year (state / municipal / enterprise)	Started-closed	Pollutants	Method	Maximum number of stations in operation during one year (state / municipal / enterprise)	Started-closed
SO_2, NO_2, TSP, CO, NH_3, HCl, formalde-hyde, phenol, heavy metals (Cd, Cu, Pb, Zn) in TSP	**5** (5/0/0)	1969 - 1997	SO_2, NO_2, O_3, benzene, toluene, xylenes	DOAS	**7** (4/2/2)	1994[2]
			NO, NO_2, benzene	Gas chromatography	**1** (0/1/0)	2003
			O_3	UV spectrophotometry	**1** (0/1/0)	2003
Heavy metals (Cd, Cu, Pb, Zn, Ni, As, Mn) in PM_{10}	**3** (2/0/1)	2000	PM_{10}	Beta ray attenuation	**4** (2/1/1)	2000
			CO	Infrared spectrophotometry	**1** (1/1/0)	2002
			Hg fumes	Mercury vapor atomic absorption	**1** (1/0/0)	2000-2002

Notes: TSP - Total suspended particulates

[2] As municipal monitoring; state monitoring was launched in 1998

2.3. EnviMan – a complex AQ data storage, management and modeling system

Development of strategical and technical methods for monitoring measurements and data handling manners go hand in hand depending on progress in information technologies. Till 1991 all data were stored on paper sheets only, but since 1991 - digitally and with duplicated reserve copies on paper formats, as the safe maintenance of digital data is not fully ensured yet. The software used were FOXPRO.

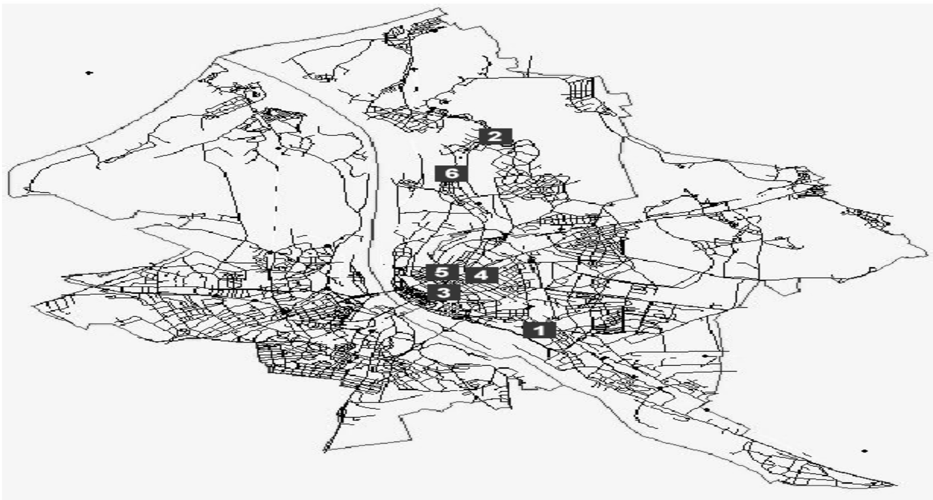

Figure 2. Schematic state and municipal AQ monitoring network in Riga in 2004-2005 (indication of stations corresponds to those given in the Table 3) (Šteinberga et al., 2005).

The newest tool for data management and pollution's dispersion assessment EnviMan, which is coupled with DOAS observation's stations and produced by OPSIS AB Company in Sweden, was obtained in the LEGMA in the late 1990-ties. Initially it was used for processing and storage of data gathered from automatic monitoring stations only. First AQ modeling exercises using EnviMan began in 2000 – 2001 when digital map of Riga City and related GIS databases with regard to emission point sources as well as input meteorology data were prepared. Nowadays AQ modeling with EnviMan is broadly used for permitting purposes to regulate release of air pollutants from industrial installations.

The similar EnviMan system is located in the Air Quality Division of the Environmental Department of RCC. So, the data storage from municipal observation's stations is duplicated both in LEGMA and Riga municipality (Table 3).

2.4. AQ management system: from reliable data to on information based decisions and informed society

Ambient air monitoring system as well as set of AQ standards are established on the basis of relevant EU directives incorporated into the environmental legislation of Latvia. According to legislative provisions and taking into account the results of AQ assessment covering time span 1998-2003, the Ministry of Environment restated 2 zones for AQ management and assessment in Latvia in 2004 - Riga agglomeration and the rest of the country (initially, there were Riga agglomeration and 2 additional zones nominated in 2003).

The main AQ problems in Riga are represented by elevated concentrations of NO_2, PM_{10} and benzene. All responsibility for improvement of AQ in Riga agglomeration is delegated to Riga City Council (RCC). Due to before mentioned AQ problems RCC was obliged to prepare action plan on improvement of AQ in Riga agglomeration. RCC has announced the tender for preparation of related action plan in 2003 and such a plan was elaborated by the Latvian consultancy company "Eiroprojekts".

Table 3. Structure of AQ monitoring system in Riga in 2005

Nr.	Name of station	Type of station	Monitoring system	Financier	Technical maintenance and data QA/QC	Place of data storage	Main pollutants measured
1	Ķengarags	Urban background	State	LEGMA	LEGMA	LEGMA	SO_2, NO_2, O_3
2	Mīlgrāvis	Urban background	State	LEGMA	LEGMA	LEGMA	SO_2, NO_2, O_3, benzene
3	Parks	Urban background	State	LEGMA	LEGMA	LEGMA	SO_2, NO_2, O_3, PM_{10}, heavy metals in PM_{10}
4	Street Brīvības	Traffic	Municipal	RM	LEGMA	LEGMA RM	SO_2, NO_2, O_3, PM_{10}, benzene, heavy metals in PM_{10}
5	Street Valdemāra	Traffic	Municipal	RM	LEGMA	LEGMA RM	NO, NO_2, O_3, PM_{10}, CO, benzene
6	Street Tvaika	Traffic	Municipal	RM	LEGMA	LEGMA RM	SO_2, NO_2, O_3
7.	Port 1	Industrial	Enterprise	RCFP	LEGMA	LEGMA	SO_2, NO_2, PM_{10}, benzene, toluene, xylenes, heavy metals in PM_{10}
8.	Port 2	Industrial	Enterprise	RCFP	LEGMA	LEGMA	SO_2, NO_2, benzene, toluene, xylenes

Notes: 1. LEGMA - Latvian Environment, Geology and Meteorology Agency;
RM – Riga Municipality;
RCFP - Riga Commercial Free Port
2. Heavy metals include Pb, Cd, Cu, Zn, Ni, As, Mn

The action plan is approved by RCC in 2004 and it comprises actions to be carried out until 2009 (Table 4).

Table 4. Action plan on improvement of AQ in Riga agglomeration – summary on planned activities

Nr.	Activity	Description	Time	Expected results
1.	To state AQ as an obligatory criteria for elaboration and review of city development plan as well as for optimization of traffic system in the city.	Riga City Council decision	2004	Effective introduction of AQ action plan
2.	To decrease the amount of traffic in the historical center of the city by 35 % compared to 2002 performing optimization of the traffic.	One of the objectives stressed in the Riga City development plan 2006-2018. Restrictions to traffic, restructuring of traffic flows, avoiding of traffic jams, setting of differentiated starting time for work of authorities and enterprises.	2009	Decrease in NO_2 pollution caused by traffic to the limit value.
3.	Wet cleaning of streets and pavements in the city center during spring-autumn seasons.	Regularly during days without pronounced precipitation.	Steadily since 2005	Gradual decrease in particulate matter pollution caused by traffic. Combination with other measures (see Nr. 1) will lower concentration to the limit value until 2008.
4.	Elaboration of regulations of Riga City Council on zoning of air pollution for development of heat supply in Riga.	Actual and forecasted NO_2 pollution must be taken into account when allowing differentiation of heating systems. All pollution sources including small ones must be enumerated.	2004-2005	Decrease in NO_2 and PM_{10} caused by stationary pollution sources.
5.	Elaboration of new conception on heat supply in Riga for coming 10-15 years.	Modernization of 2 main steam shops supplying heat in Riga (until 2009).	2004-2005	Considerable decrease in air pollution.
		Gradual replacement of coal based small boiling houses to gas or wood burning installations (until 2009).		
6.	Strengthening of AQ monitoring system in Riga.	Expansion of existing monitoring network with 4 stations measuring PM_{10}. Upgrading of benzene analyzers of DOAS monitoring stations within state network.	2005	Proper information gathered and society informed, possibility to assess introduction process of the plan.
7.	Introduction and maintenance of AQ monitoring system in the territory of Riga Free Port.	Possible expansion of the observations network if oil loading terminals will be	Since 2004	Follow-up of air pollution caused by port operations.

Table 4 (continued)

Nr.	Activity	Description	Time	Expected results
		expanded. Installation of meteorological station (2004).		Measures on pollution restriction.
8.	Strengthening of Environmental Department of Riga City Council and establishment of system of supervision and control on air pollution reduction.	Establishment of 4 additional new working places within Environmental Department.	2005	Established system of supervision and control on air pollution reduction.
9.	Involvement of public by establishment of interactive system of information exchange.	Information system about AQ, measures taken and results achieved. Understandable interpretation of information dedicated to public.	2005	Enhanced effectiveness of introduction of AQ action plan.

In order to get the necessary information on AQ, all available information sources have been used – data generated by AQ monitoring, statistics on air emissions gathered by Riga Regional Environmental Board and compiled by LEGMA and Central Statistical Bureau of Latvia and AQ modeling especially in relation to different development scenarios, which could change the air emissions and related AQ situation. Although pollution generated by traffic is evaluated on the basis of amount of cars and pollution factors, routine assessment methods must be refined.

The main objective of the action plan is to lower the elevated air pollution to the level that corresponds to AQ good enough for human health protection as well as to implement preventive measures for places of already satisfactory AQ but of potential risks in the future due to possible development of traffic and industrial activities. Priority targets were defined mainly based on costs - benefits analysis as well as on forecasts of possible changes in AQ taking into account temporal dynamics of air emissions. Additionally, different scenarios were analyzed with respect to social and economical development, potential changes in legislation and residential areas (Steinberga, 2005).

As it was already mentioned, regardless of different property and financing characteristics of the monitoring stations all of them are technically and methodologically (data QA/QC) maintained by LEGMA. More diverse and fully separated are information dissemination patterns including on-line access to information published on Internet homepages both of LEGMA and the Riga City Environment Center "Agenda 21" (www.lvgma.gov.lv and www.agenda21riga.lv, respectively). Both LEGMA and Riga municipality are reporting on-line and monthly AQ information to the public obtained within their own observations network only. However, yearly reports on AQ prepared by LEGMA comprise full analysis on the AQ situation in Riga (Šteinberga, et al., 2005). All kind of reports is freely available on the Internet, though, almost only in Latvian for the moment. It must be emphasized that Riga municipality applies integrated AQ index in order to inform public in an understandable way, however, integrated AQ indexes are not supported by environmental legislation.

3. CONCLUSIONS

3.1. Complex AQ management system consists of a number of elements which could be divided into four main functional blocks: 1) Data and information generation and gathering; 2) Assessment, reporting and dissemination of information; 3) Decision making and public involvement; 4) Implementation of actions.
3.2. Environmental monitoring plays the key role in supplying environmental information useable for management purposes. In order to reach an appropriate coverage in a large city monitoring network must combine networks of different actors – state, municipal, enterprise, etc. The most effective and cheapest way is to centralize the technical and methodological (QA/QC) maintenance of all AQ observations under one authority having skilled and experienced staff.
3.3. The same considerations relate to information dissemination, which must be organized on the integrated basis – the public must have the possibility to obtain all the AQ information at one place what is not a case for Riga City at the moment.
3.4. Successful AQ management in a large city depends on cooperation and networking of all actors involved but it is not easy to avoid no needed competition among authorities and to break institutional barriers.
3.5. Main AQ problems in Riga - the only one agglomeration nominated in Latvia as an AQ management and assessment unit according to EU legislation, are manifested by elevated concentrations of NO_2, PM_{10} and benzene exceeding the related limit values.
3.6. Action plan on improvement of AQ was prepared taking into account monitoring data, results of AQ modeling and different development scenarios associated with different air emissions. Riga City Council approved the action plan in 2004. It foresees more or less concrete measures until 2009. Strengthened AQ monitoring network in Riga must prove success of measures implemented and indicate to targets, which are to be reconsidered.

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