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Chapter 5

Information Systems for Air Quality Monitoring

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Additional information is available at the end of the chapter

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1. Introduction

Today, for the successful performance of the work of monitoring air quality information system is essential. Before some 30-odd years ago when it was beginning to monitor air quality measurement results were written on paper in the table. Increasing use of computer data has begun to digitize. "Database" or tables were first written on the magnetic tape, then on floppy disks, CDs and DVDs. Today, air quality monitoring is impossible to perform without the use of computers and information systems.

2. Information systems

In developing (design) information system for monitoring air quality you must look primarily to the needs of users and data collection methods. Will the information system only collect data and store them in a database, or would have done, and other functions to the data (e.g. calculating AQI, making DEM files, perform data validation, forecasts data, etc.). In addition you have to look at the methods of collecting. If you can only use so-called "Manual methods" data must be manually entered into the system, however if you are using automatic methods data are automatically entered into the system. Very often, information systems for monitoring air quality are made because of changes in the law on air protection, or the suggestions of the competent institutions. If an information system developed for the needs of state institutions or the information that is obtained through an information system is to be forward to the government institutions or later perhaps even to international institutions (e.g. European Environment Agency (EEA)) then the information systems must operate according to certain standards. EEA has issued standards for the development of information systems [1]. Such a rule is a well-respected if the information system developed for the needs of the agency that will directly communicate with the EEA.

When designing information systems people often uses three-tier system architecture (Figure 1). This architecture consists of three layers. In the first layer there are databases, on

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second layer other helper applications, services and systems, and the third layer there are applications that use the data, other information systems or end users.

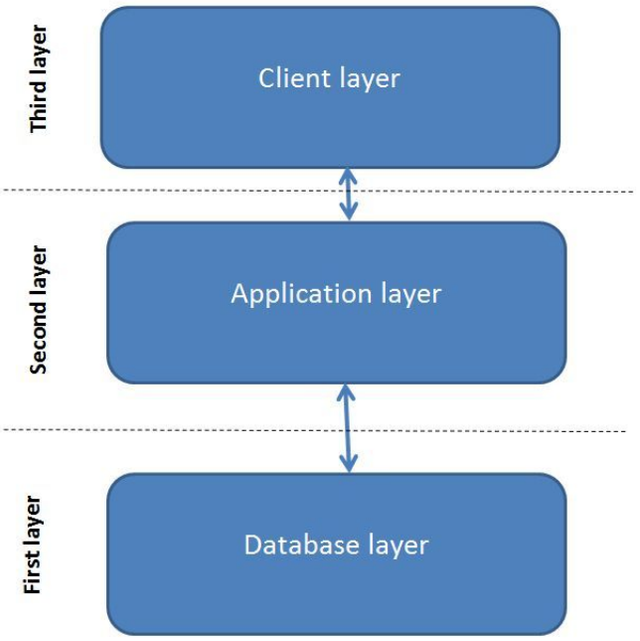


Figure 1. Three-tier architecture of the information system

The preparation of an information system can be divided into software and hardware part. When we talk about the software part we think of the database, various applications to perform various tasks in information systems, services that are needed to operate the information system. While the hardware components are talking about devices for the analysis of the air and on the communication devices that are connected to the information system. First we handle the software and then the hardware part of the information system.

3. The software part of the information system

3.1. Databases

Nowadays the amount of data that has to do with the information system for air quality is enormous. Several years ago, data on air quality were recorded in the tables in different programs (e.g. MS Excel, Quattro, etc.), but such programs are unsafe and not used for storing data, but for their treatment.

These types of programs are called flat files (executable files). The main problem with such files (or such an organization) is to write to physical media (hard disk, CD, DVD, etc.) depends on the media, also with them we cannot talk about any kind of organization the additional data. Other problems that exist among them are:

- competitiveness - at one point the data can access more than one person or one application;

- Integrity - when multiple applications are using the same information (i.e. information), there may be a problem or an error in the data because there is no control of access to data;
- Relationships - set a relation or connection between the data is impossible because there is no predefined structures;
- Re-utilization - direct files are designed for a specific system and cannot work on another (e.g. Doc files do not work on Mac OS or Unix operating system because they are designed to operate on the Windows operating system);
- Security - when it comes to security files, we cannot talk about a common method of providing access to data and are therefore vulnerable to unauthorized access to data.

When all this is taken into account, the question is what would be the definition of a database? The database is a collection of interrelated data stored in external memory and simultaneously available to various users and applications.

The data of a database are stored as files on your computer. In the previous section we talked about random files are also stored on your computer. So the question is how is it different than the database files directly? If we think, we realize that actually the database itself and not much more than what we used to direct the file. That of which we have great benefit is the DBMS (DataBase Management System) system or database management. DBMS server is actually located between the database and its users. He actually performed for us all database operations

Today there are several freeware and commercial DBMS's (MySQL, PostgreSQL, Microsoft Access, SQL Server, Oracle, etc.). DBMS not only retrieves data from the database but is also responsible for adding them, changing and deleting, for storing backups, keeping the integrity of the database, authenticate users who access the database and watch the simultaneous database access by multiple users. The most important advantage that distinguishes a database from a direct file is independent of data provided by the DBMS.

The data in the database are logically organized in accordance with some of the data model. The data model is a set of rules that determine how it may appear logical structure of the database. Models of data from the oldest to the newest are listed below.

- **Hierarchical Model** - in a hierarchical database model is presented to a tree or a set of trees. Nodes represent the types of records, while the hierarchical relationships expressed attitude "superior - subordinate".
- Network Model - when the network database model is presented directed graph. Nodes are the types of records, and the links between them are defined arches. The previously mentioned hierarchical model is actually a special case of network models.
- The relational model - it is based on the mathematical notion of relation. When it presents the data in tables. These tables are connected by links to avoid redundancy (repetition), integrity (wholeness) of the data and to maximize the speed of searching the database.

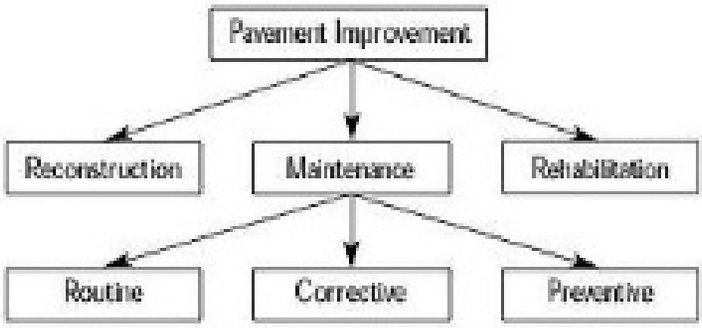


Figure 2. An example of hierarchical models

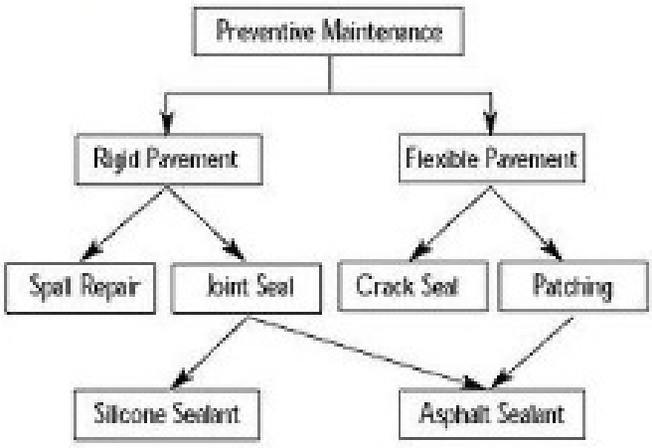


Figure 3. Example of network model

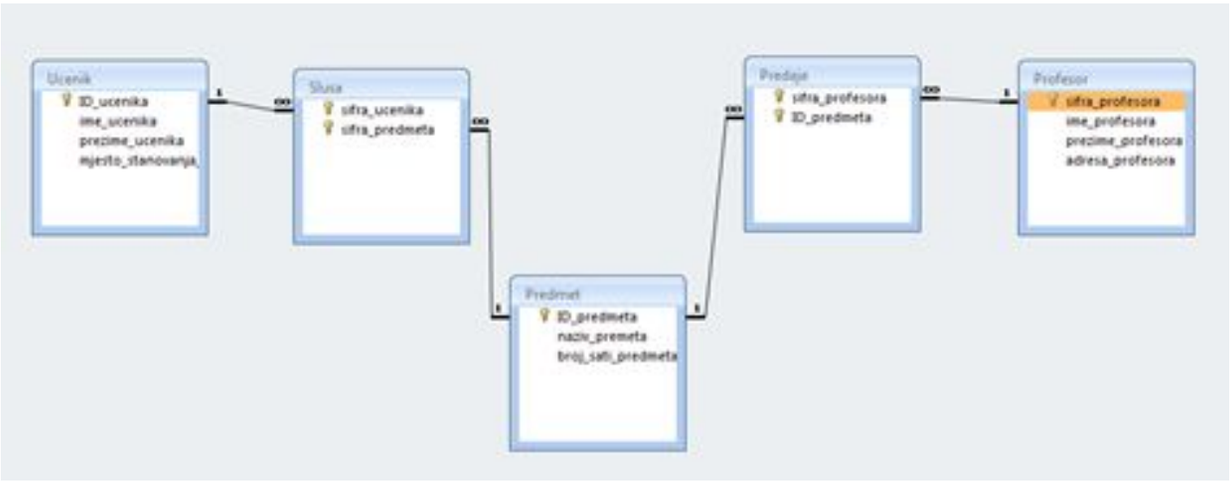


Figure 4. An example of the relational model

- **Object model** - the object model is inspired by object-oriented programming languages. The database is a collection of permanently stored objects that consist of its internal data and methods for working with these data. Each object belongs to a class and the connection is established between classes inheritance, aggregation, or mutual use of operations.

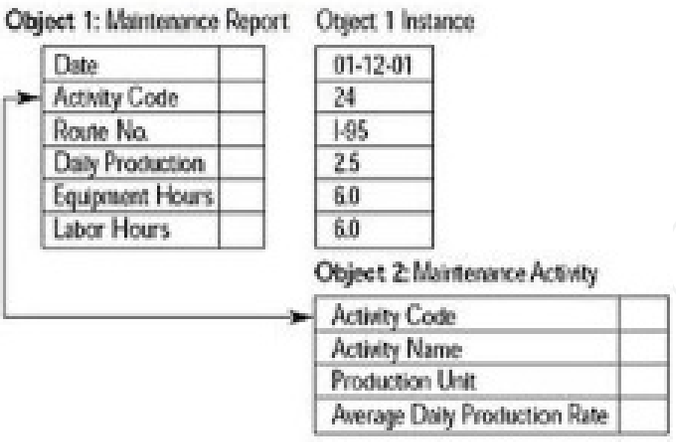


Figure 5. Example of object model

- **Semi structured Model** - in such models the information that would otherwise be normally connected to the scheme are within the data. The advantages are that it can be used to display information about the data that other models do not support, and providing flexible format for exchanging data between different types of databases

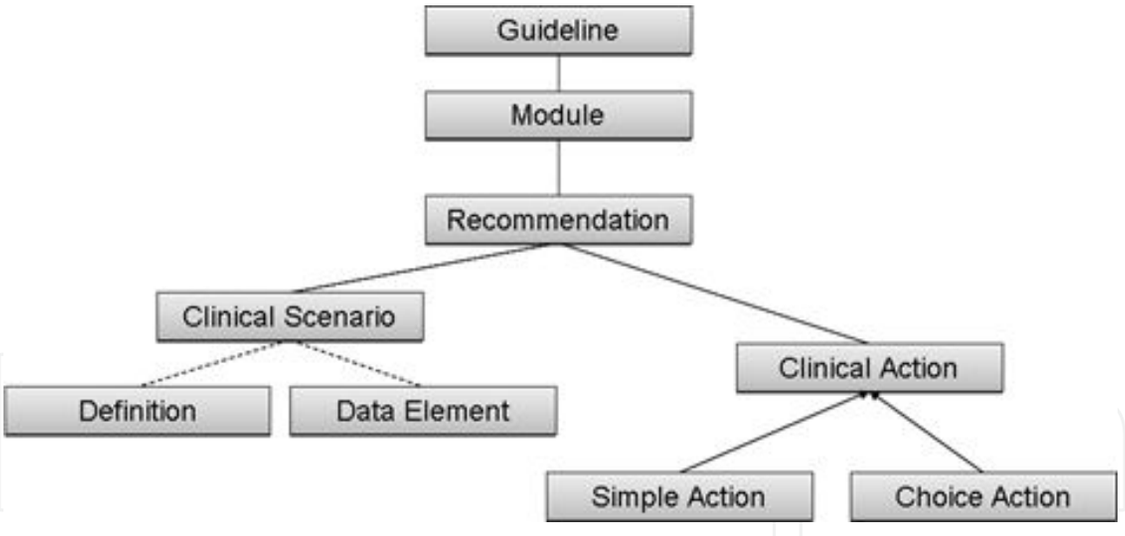


Figure 6. An example of semi-structured models

- Semantic (RDF) Model - allows the organization and management of unstructured data. Mostly to be encountered when connecting XML documents in database.
- Geospatial Model - At this time more and more data related to the Earth's surface and to the need for analysis, visualization and distribution of such data types. In principle, it is a combination of relational and object models (because they did not support relational spatial and temporal component object model and has not had a good enough standard).

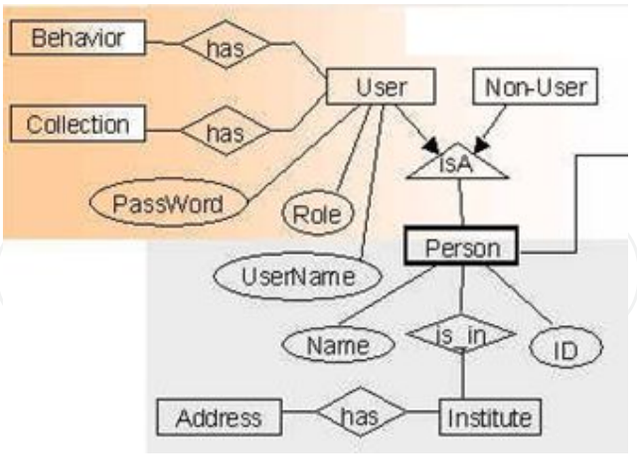


Figure 7. An example of RDF models

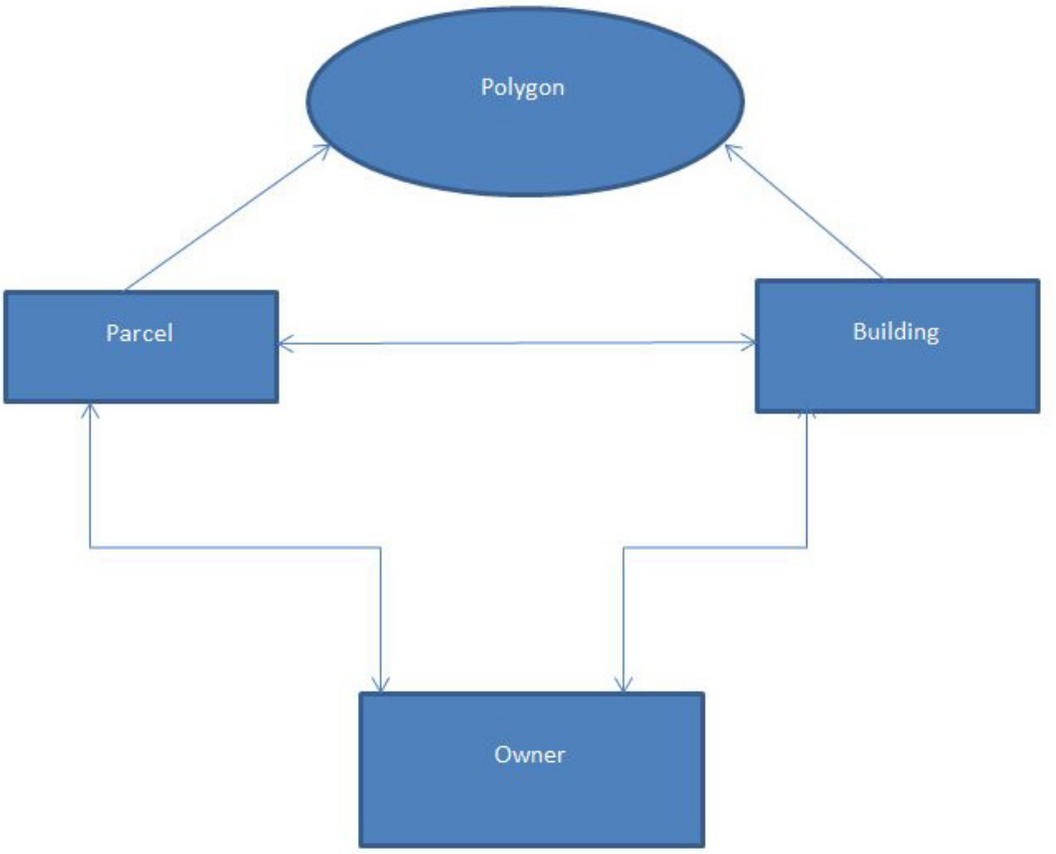


Figure 8. An example of geospatial models

Each model has its bad and good sides. Somewhere in the 80-ies of the relational model is becoming increasingly popular due to its simplicity and short time to overcome. In contrast, the object model is a lot more powerful than all other models, but also more complicated and there are still no generally accepted standards. Geospatial model began to develop rapidly in the last 10-odd years along with a comprehensive application of the GPS system

and use geographic coordinates as in science and research segment, as well as economic, military, technological and political environment.

When we look only information systems for monitoring air quality the most common model used is relational, however, at the Institute for Medical Research and Occupational Health (IMROH), we started with the experimental use of geospatial models. Why geospatial model for monitoring air quality? If you look at the data that is handled first, we can see that they are dependent on the temporal and spatial components. Data obtained from the monitoring stations are different for each time of day and also demonstrated their dependence on weather conditions [2]. Because of these characteristics of air pollution, and also because of air pollution were never a point in the air but the best I can describe irregular three-dimensional geometric figure, we believe that it is the easiest and best described in a geospatial model. Tests of such models are only just beginning and it will take some time if and when this model began to be used in larger information systems.

What is for sure the database is the foundation of information system and therefore in its design must be given enough attention. If in the early design phase of information system in preparing the database we detected possible problems later, they can be corrected or avoided.

3.2. Applications

After the databases themselves, very important element of information systems for monitoring air quality are applications that are required for monitoring air quality such as application for DEM files and applications for the AQI.

3.3. DEM files

Within the European Union adopted method for transferring data between institutions within countries and within countries. The Data Exchange Module (DEM) can be used to exchange of information on air quality data (i.e. raw data, statistics and ozone exceedances) and meta information on operational air quality networks, stations and measurement configuration [3,4]. The file format for Air Quality DEM was developed by the European Topic Centre on Air and Climate Change (ETC / ACC), and every institution that sends data to the EEA must send DEM files prepared in that format [4].

There are many free or commercial applications such as Data Communication Server or DEM for creation DEM files.

Application Data Communication Server 2008 is created by the GEMI GmbH. The application is designed in a way that takes data directly from the database converts them into DEM files and saves them on hard disk. Application DEM v14.0 is the latest version that was created in 2011 by the European Topic Centre for Air Pollution and Climate

Change (ETC-ACC) (Figure 9). The application is mainly intended for working with large networks of stations for monitoring air quality, such as the National Network.

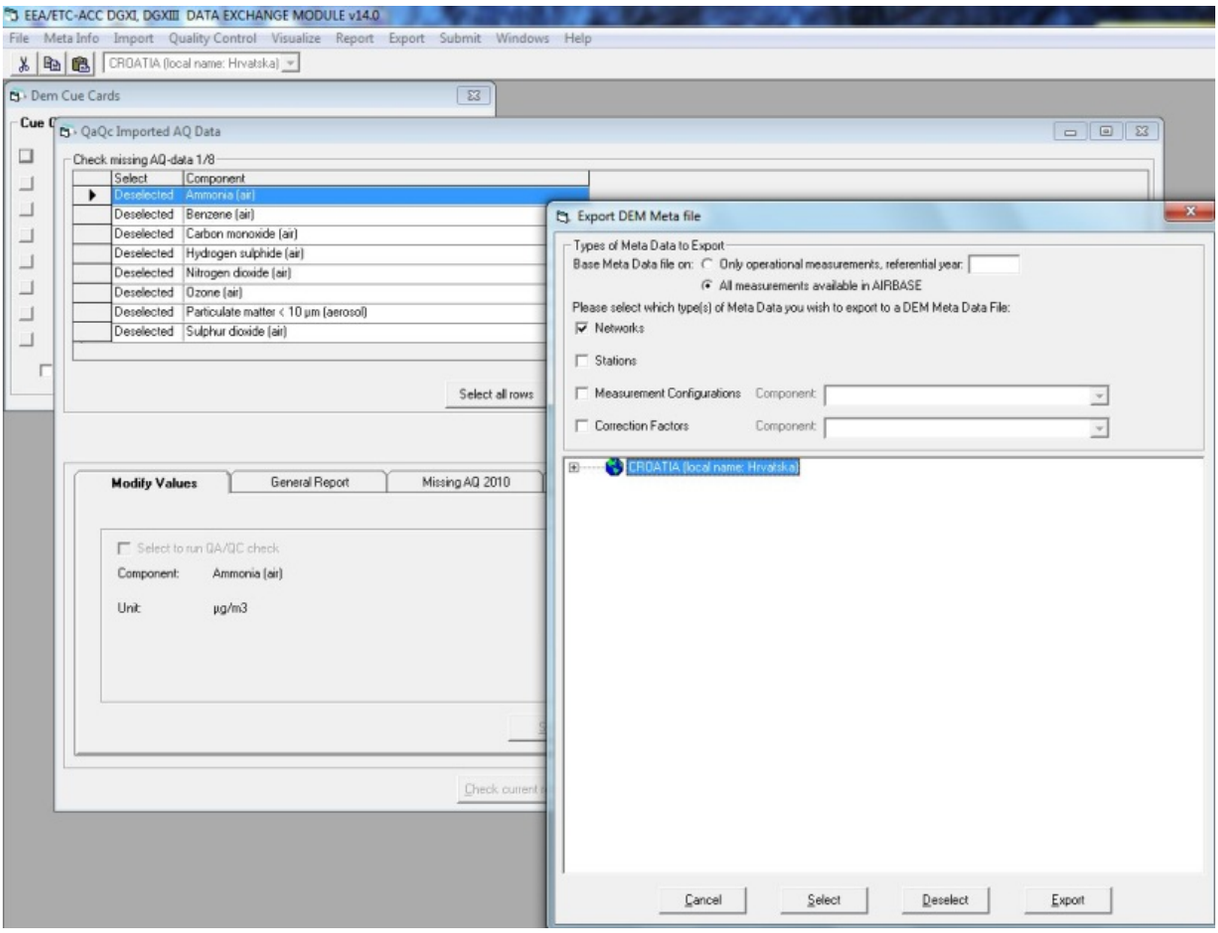


Figure 9. DEM v14.0

Each application has its advantages and disadvantages, so if you cannot find an application that will meet the specific requirements for each information system you can always make your own applications. Of course it is necessary to follow the instructions that gave ETC / ACC regarding looks DEM files [5].

3.4. AQI

Air Quality Index (AQI) is also one more very common application that meets the information systems for monitoring air quality. AQI serves as an indicator of reporting daily air quality. It shows how clean or polluted the air and what the possible health problems could be caused by inhaling air. AQI focuses on health effects that may be caused by inhaling polluted air during a few hours or days. The European Union uses mostly CAQI (Common Air Quality Index) air quality model calculations [6]. In CAQI air quality index can have values from 0 to 100. What is the index value lower, the better air quality is. For this measurement number 75 represents the presence of low levels of each pollutant, the level below the legally prescribed limit value. Therefore, the air quality index below 75

represents good air quality and little possibility of causing health problems of the population. Also the air quality index scale is divided into five different colored categories, from green to red. For example, the index value of 27 drops into the green-yellow zone, this indicates good air quality. On the other hand, values above 101 belong to the red zone, which points to the danger.

Index class	Grid	Traffic				City Background					
		Mandatory pollutant			Auxiliary pollutant	Mandatory pollutant				Auxiliary pollutant	
		NO_2	PM_{10} 1-hour	PM_{10} 24-hours	CO	NO_2	PM_{10} 1-hour	PM_{10} 24-hours	O_3	CO	SO_2
Very low	0	0	0	0	0	0	0	0	0	0	0
	25	50	25	12	5000	50	25	12	60	5000	50
Low	26	51	26	13	5001	51	26	13	61	5001	51
	50	100	50	25	7500	100	50	25	120	7500	100
Medium	51	101	51	26	7501	101	51	26	121	7501	101
	75	200	90	50	10000	200	90	50	180	10000	300
High	76	201	91	51	10001	201	91	51	181	10001	301
	100	400	180	100	20000	400	180	100	240	20000	500
Very High*	> 100	> 400	>180	>100	>20000	> 400	>180	>100	>240	>20000	>500
NO_2, O_3, SO_2:		hourly value / maximum hourly value in $\mu g/m^3$									
CO		8 hours moving average / maximum 8 hours moving average in $\mu g/m^3$									
PM_{10}		hourly value / daily value in $\mu g/m^3$									

* An index value above 100 is not calculated but reported as "> 100"

Figure 10. Table for CAQI model (taken from http://citeair.rec.org)

Another very popular Air Quality Index was developed by the United States Environmental Protection Agency (EPA) [7]. In their index value is 0-500. The higher the AQI value, the greater the level of air pollution and the greater the health concern is. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA, has set to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy-at first for certain sensitive groups of people, then for everyone as AQI values get higher.

Each category corresponds to a different level of health concern. The six levels of health concern and what they mean are:

- "Good" AQI is 0 - 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- "Moderate" AQI is 51 - 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.

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

Figure 11. Example table AQI developed by EPA (taken from the site http://www.airnow.gov/index.cfm?action=aqibasics.aqi)

- "Unhealthy for Sensitive Groups" AQI is 101 - 150. Although general public is not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.
- "Unhealthy" AQI is 151 - 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.
- "Very Unhealthy" AQI is 201 - 300. This would trigger a health alert signifying that everyone may experience more serious health effects.
- "Hazardous" AQI greater than 300. This would trigger a health warning of emergency conditions. The entire population is more likely to be affected.

Applications for calculating the AQI rule does not exist. There are several variants of a program for calculating the AQI in MS Excel. So those responsible for the information system monitoring the air quality must themselves make the necessary application to display the AQI based on a model they choose.

3.5. Website

Another very important part of information system for monitoring air quality is a web page or web site. In it you can show some important information related to the quality of the air, warning to the citizens about pollution and archive data for previous days, months and years. What information will be displayed on the website depends on the interest of citizens for air quality and capabilities of the institution itself.



Figure 12. Examples of web pages to display the air quality (http://kvaliteta-zraka.imi.hr/ ; http://uk-air.defra.gov.uk/ ; http://airnow.gov/ ; http://www.airqualitynow.eu/)

4. The hardware part of the information system

4.1. Measuring devices

The most important part in making information systems are measuring instruments for analyzing air quality. There are various companies that produce them, which will be chosen depends on the person who purchased them.

Automatic analyzers used by IMROH for monitoring gaseous pollutants are trademarks Horiba. We pick them because of good service and the existence of accredited calibration laboratory in Croatia. All Horiba devices have the ability to display data every 3 minutes, half hour, hour or every 3 hours. Three minute value is obtained by taking the average value of the seconds for 3 minutes. Half-hour value is the average value of three-minute value in half an hour. 3-hour value is the average value of the half-hour values in these three hours. Hourly value of the integration of information that is obtained by dividing the measured value (current value) measured every second with 3600 and adding these data for a particular accounting period. Maximum capacity of memory measured data for 3-minute

value, the value of half-hour and hour value is 1000 data; a three-hour value is 100 data. The temperature of the room in which the devices can be found in the range of 5 ° C to 40 ° C, although the device works best at a temperature of 20 ° C. Automatic methods for monitoring the mass concentrations of gases at reference methods.



Figure 13. APOA 370 [8]



Figure 14. APOA 360 [8]

Automatic analyzer Horiba APOA 370/360 is used for measuring the concentration of ozone in the air. The analyzer uses a cross-modulation UV absorption method. The range of detection of mass concentrations that can be measured ranges from 0 to 1.0 ppm. The minimum detection sensitivity is 0.5 ppb for the range of 0 to 0.2 ppm, and for a range of up to 1 ppm sensitivity is 5 ppb. The analyzer automatically changes the range of detection. The analyzer has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 2.143). Sample collection rate is 0.7 l / min.



Figure 15. APSA 370 [9]

Automatic analyzer Horiba APSA 370 is for measuring concentrations of sulfur dioxide in the air. The analyzer uses ultraviolet fluorescence method. The range of detection of mass concentrations that can be measured ranges from 0 to 10 ppm. The minimum detection sensitivity is 0.5 ppb for the range of 0 to 0.2 ppm, and for a range of up to 10 ppm sensitivity is 5 ppb. The analyzer automatically changes the range of detection. The analyzer has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 2.86). Sample collection rate is 0.7 l / min.



Figure 16. APNA 370 [10]



Figure 17. APNA 360 [10]

Automatic analyzer Horiba APNA 370/360 is used for measuring concentration of nitrogen oxide in the air. The analyzer uses a cross-modulation chemiluminescence method. The range of detection of mass concentrations that can be measured ranges from 0 to 10 ppm. The minimum detection sensitivity is 0.5 ppb for the range of 0 to 0.2 ppm, and for a range of up to 10 ppm sensitivity is 5 ppb. The analyzer automatically changes the range of detection. The analyzer has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 1.34 for nitrogen oxide (NO) and 2.054 for nitrogen dioxide (NO2)). Sample collection rate is 0.8 l / min.



Figure 18. APMA 370 [11]

Automatic analyzer Horiba APMA 370 is used to measure the concentration of carbon monoxide in the air. Cross-modulation analyzer uses non-dispersive infrared spectroscopic method. The range of detection of mass concentrations that can be measured ranges from 0 to 100 ppm. The minimum detection sensitivity is 0.5 ppm for the range of 0-100 ppm. The analyzer automatically changes the range of detection. The analyzer has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 1.25). Sample collection rate is 1.5 l / min.



Figure 19. APSA-H370 [12]

Automatic analyzer Horiba APSA H370 is used to measure the concentration of hydrogen sulphide in the air. The analyzer uses the method of oxidation catalysts in combination with UV fluorescence. The range of detection of mass concentrations that can be measured is in the range from 0 to 1 ppm. The minimum detection sensitivity is 1 ppb for the range of 0-1 ppm. The analyzer automatically changes the range of detection. The analyzer

has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 2.86 for sulfur dioxide and hydrogen sulfide to 1.521). Sample collection rate is 0.7 l / min.

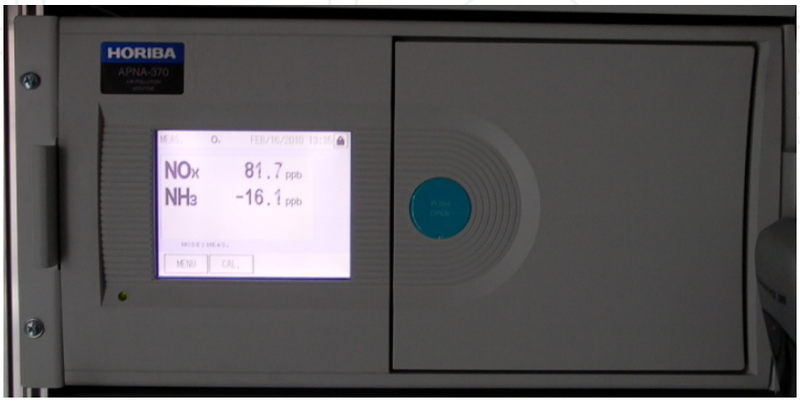


Figure 20. APNA 370 [13]

Automatic analyzer Horiba APNA 370 is used to measure the concentration of ammonia in the air. The analyzer uses the method of oxidation catalysts in combination with UV fluorescence. The range of detection of mass concentrations that can be measured ranges from 0 to 0.5 ppm. The analyzer automatically changes the range of detection. The analyzer has the option of displaying the mass concentration in ppm or mg/m^3 (with a correction factor of 0.76 for ammonia). Sample collection rate is 2 l / min.

Particles that are considered to be pollutants in the air and for which medical and scientific evidence that environmental impact on air quality are particles PM10 (diameter less than 10μm), PM2.5 (diameter less than 2.5μm) and PM1 (diameter less than 1μm).

5. Automatic methods

An automatic method used at the IMROH is reduced to an automatic device Verewa Beta-Dust Monitor F-701-20 [14]. The device shows the mass concentration of particles in mg/m^3. Mass concentration of particles is determined by radiometric method. Radiometric measurement is done using the Beta transmitter (C-14) and Geiger-Müller counters. The range of detection is in ranges from 0 to 10 mg/m^3. The minimum sensitivity of detection is 0.001 mg/m^3. The device has a heated tube so that at low temperatures there is no formation of ice inside the pipe. Will it be collecting particles of PM10, PM2.5 or PM1 only depends on the head with nozzles of different diameters. Sampling rate is 1000 l/h. Sample collection time is one hour, but the device has the ability to display the current value of the mass concentration. Automatic methods for collecting airborne particles are not the reference methods.



Figure 21. Verewa Beta-Dust Monitor F-701-20

6. Manual methods

Manual method for measuring the mass concentration of particles in the air is gravimetric. Gravimetric method is very strictly defined in the standard 12 341 [15]. That can be used gravimetric method laboratory must have a special room to hold the filter and weighing them. In gravimetric methods filters that are used for collecting samples of air must before and after sampling be specially treated. Filters before sampling must be in a desiccator at a constant temperature of 20 ° C ± 1 ° C and at a relative humidity of 50% ± 5%, for 48 hrs. After 48 hours the filters are weighed on vase sensitivity 1μg, once again returned to the desiccator for 24 hours. After 24 hours, repeat the procedure for weighing the filters and then they are ready for sampling. After re-sampling filters are placed in a desiccator for 48 hours, and weighed after 48 hours. They return back to the desiccator for 24 hours, and after 24 hours they are weighed. Only then the mass concentration of particles for the sampling day can be calculated. Gravimetric method is the reference method for determining the mass concentration of particles in the air. Mass concentrations of particles are shown in mg/m^3. The IMROH for the gravimetric method uses two types of devices. Both devices in a small flow and meet the requirements to be a reference.

Sven Leckel Low Volume Sampler LVS3 [16]

The machine uses air flow of 2.3 m^3/h. Samples are taken at intervals of 24 hours ± 1 hour. Filters used for sampling are the quartz filters 47 mm in diameter. The device has the option of taking the sample ranged from 1h to 999h; however, norms and laws stipulate that the sample must be taken 24 hours. The device allows you to adjust the flow of 1 m^3/h, 1.6 m^3/h, 2 m^3/h or 2.3 m^3/h. Also the device has a microprocessor to maintain the flow deviation <2%. Filters can be a diameter of 47mm to 50mm. What will be collected particulate fractions (PM10, PM2, 5 or PM1) depends on the head and the nozzle of the device.



Figure 22. Sven Leckel Low Volume Sampler LVS3

Sven Leckel Sequential Sampler SEQ47/50 [17]

Unlike Sven Leckel Low Volume Sampler LVS3 SEQ47/50 device does not require every day manually changing the filters but it contains a repository of multiple filters (maximum 17). Air flow that supports the 1m^3/h, 1.6 m^3/h, 2m^3/h and 2.3 m^3/h. Sampling time can be a between 1h and 168h. Filters can be a diameter of 47 - 50mm. Also the device has separate compartments for storing the sampled filter that is regulating to maintain a constant temperature of 20 ° C and relative humidity at 50%. What fraction of particles will also be collected as in previous devices depends on the head and nozzle. By their specifications of the device also meets the standard to be a reference device.



Figure 23. Sven Leckel Sequential Sampler SEQ47/50

7. Communication

Communication between devices (analyzers), in most cases is done by using some of the company's application that exist in the market. As each program and they have their advantages and disadvantages.

In most cases, information systems are not located in the same position where there are stations for air quality control so that all data must be sent from the station into the information system if possible using a network cable, or in some cases using the mobile Internet or WIFI.

8. Conclusion

The section shows the general items of an information system of monitoring air quality. A large part of the components of the information system for monitoring air quality described are at the Institute for Medical Research and Occupational Health in Zagreb. Monitoring of air quality today is unthinkable without the use of good and quality information systems.

The future of information systems at the IMROH will be improved and pollution forecasts depicting pollution using GIS technology.

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