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MONITORING SYSTEM WITH WIRELESS COMPONENTS FOR AIR POLLUTION GENERATED BY INDUSTRIAL PLANTS

Ş.P. AGACHI[*], I. STOIAN[**], E. STÂNCEL, M. CRISTEA*, S. DRĂGAN*, O. GHIRAN**, D. CĂPĂŢÂNĂ**, A. IMRE*, A. GHIRIŞAN*, ŞT. HEGHEDUŞ**, C. POSTEUCĂ**

[*] *Department of Chemical Engineering, Faculty of Chemistry and Chemical Engineering, Univ. Babeş-Bolyai Cluj-Napoca*

[**] *S.C. IPA S.A. Bucharest, Research, development and technological ransfer center (CIFATT) Cluj-Napoca,*

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ABSTRACT. This paper presents *WIPOL*, a monitoring system for air pollution generated by industrial plants with wireless components. The system is developed to supervise the air pollution generated by industrial plants, especially dust. Two industrial plants are monitored using a hierarchical system of sensors and computers including wireless components.

1. INTRODUCTION

In nowadays the environment protection is one of the most important problems. The pollution of the air with dust, particles, smoke and vapor gas is a complex problem due to the variety of the pollutants from industry, agriculture, transport, and energy production.

The environment quality at a specific moment depends on the quality of the air, water and soil, the health of the population and deficit of the plants and animals species in the analyzed area. All of these factors are expressed by some indicators of the quality with specifically limits [1]. For example, the natural, unpolluted air has the next composition: 78 % N_2, 21 % O_2, 0.03 % CO, 0.93 % Ar and 0.04 % CH_4.

The main pollutants for the air are: CO, $(SO)_x$, $(NO)_x$, H_2S and dust. The air quality management of the air could be solved by: determination of the distribution of the pollutants and by determination of the correlation between the quality of the air and the distribution of the pollutants.

The estimation of the pollution produced by a chemical plant or equipment (apparatus) represents a requirement in the design step of the plant (ISO norms, ISO 14000 in EU area). Beginning December 1995 in Romania it is applied a new law for the environment protection (Law 137/1995). The disposal 184/1997 contains the means and procedures to carry out the balance of the pollutants. The disposal 756/1997 contains the rules for the estimation of the pollution of the water, air and soil. HG. 34/2002 contains the rules to prevent, reduce and control the pollution and the limitation of the CO, SO_x, NO_x, dust in suspension (PM_{10}) and ($PM_{2,5}$), Pb, benzene and O_3 in the environment.

2. CHARACTERIZATION OF THE INDUSTRIAL POLLUTANTS

The **WIPOL** monitoring system was developed to trace the pollutants from two main industrial sites: **S.C. CASIROM S.A. Turda** and **S.C. SOMEŞUL S.A. Dej** companies.

S.C. CASIROM S.A. Turda is the only plant in our country, which produces refractory products necessary in the metallurgical, glass and coke industry. From 1985 the plant **S.C. CASIROM S.A. Turda** produces abrasive materials too.

The pollutants from **S.C. CASIROM S.A. Turda** are from the department of refractory products and from the department of CSi.

– ***dust*** from technological process: grinding and milling of the quartz, sand and lime, transport of the row materials, sorting out of materials on the vibrator sieves, drying of the refractory products;

– ***gases*** from the combustion in the furnace Mendheim as *CO*, NO_x, SO_2;

– ***volatile organic compounds*** *(VOC)* from the chemical reaction.

The dust is formed from particles, 70 % from this particle have the diameter between 0.5–2 mm. This means that the particles will settle in the near proximity of the department (inside the plant).

The gaseous products are: SO_2 – in the process of CSi production due to the presence of the S (0.6–6 %) in coke (2 g/m^3), and SO_x, NO_x, CO, NO_x, and VOC from oxidation, combustion and reaction.

The evacuation of the pollutants could be made in two different ways: a) systematically through pipes and ventilation outlets in known and controlled concentrations and flows; b) unsystematically through orifices and areas with unknown flows and concentrations.

At **S.C. CASIROM S.A. Turda** the evacuation of the gases from the combustion is made through the dust funnel (with H = 10 m and D = 0.9 m), with a flow of 150 m^3/h.

The balance of the pollutants in this area shows that the environment is very strongly affected. The monitoring of the pollutants and the application of the control for preventing the pollution is a necessity in this area.

S.C. SOMEŞUL S.A. Dej is a cellulose and paper plant. In the paper and cellulose preparation at **S.C. SOMEŞUL S.A. Dej** the main pollutants are: dust with particles and smoke and gas pollutants (CO, CO_2, NO_x, C, H_2S, Cl, and ClO_2) from the spinning of the wood, from the combustion and from the fabrication of the cellulose.

3. MEASUREMENT PRINCIPLES FOR FLOW RATE COMPUTATION

The methods to determine the concentration limits of the pollutants (dust, particles, smoke or/and vapor gases) in the outlet flow of the industrial plants, applied at the present in Romania, are regulated by the disposal 462/1993.

In agreement with this disposal, the measurement principle consists in the iso-kinetic sampling of a representative outlet flow. The measurement has to be made in the outlet flow having a homogenous concentration and with the highest concentration of the pollutants. The duration and the place of the measurement are variable. The norms of the environmental pollution suggest at least 3 individual measurements.

The outlet flow to be measured must be collected without perturbations. This means that it is necessary to have a linear length equivalent to 3–5 hydraulic diameters d_e in the upstream of the measurement point, where the hydraulic diameters d_e is formulated as:

$$d_e = \frac{4 \cdot A}{P_u}$$

The total flow rate will be calculated as a function of the flow, temperature and pressure [2]. The local velocity of the outlet flow determined with a Pitot-Prandl device is:

$$v = \sqrt{\frac{2 \cdot \Delta P}{\rho}}$$

The average velocity is calculated using the following equation:

$$\overline{v} = \frac{\sum_{i=1}^{n} v_i}{n}$$

The volumetric flow V (m^3/s) is defined as: $V = \overline{v} \cdot A$

Other possibilities to measure the flow are the orifice plates coupled with differential pressure manometers. With the orifice plate the flow can be calculated with the equation:

$V = K \cdot \sqrt{\frac{2 \cdot \Delta P}{\rho}}$, where K is the flow coefficient.

The outlet concentration of the pollutant can be determined using direct methods with special reactants or Dragger pump.

For the dust analysis a device with outside filter can be used. The diameter (cm) of the analyzer pipe is:

$$d = 3{,}6 \sqrt{\frac{4 \cdot V_{(t_0 + t_{efluent})}}{\pi \cdot v_{\max(p_0 + p_s in\,\sec.)}}}$$

The measurement device must be mounted in vertical position.

4. SENSORS

For the present application a specialized in-situ, continuous emission-measuring device performs the dust concentration detection.

The measuring instrumentation is based on the principle of scattering light in the forward direction, as shown in figure 1.

The Laser Diode sends a collimated and modulated light beam that is scattered by the dust particles present in the measuring zone. The scattered light is collected and then sent to a receiver diode by means of an optical fiber. An electronic circuit processes the received light beam and transforms it in an electrical signal. In order to provide independence on the disturbances, two light beams are used:

one for reference and one for measuring. The device is designed such as the velocity and electrical charge of the dust particles do not affect the measuring signal. The measuring device may be programmed via its interactive control display or with a PC via bus interface. The installation is executed on the exhaust channel using a single mounting flange. Gravimetric calibration for dust concentration in mg/l is performed at commissioning [3]. The measuring signal is sent, as an analog output current signal, to the wireless module for remote transfer.

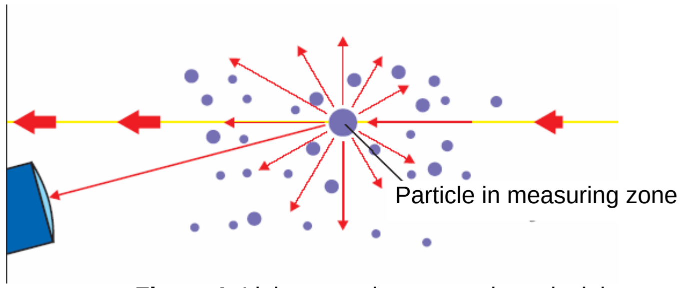


Figure 1. Light scattering measuring principle.

The measuring system may be extended, on request, with a multi component monitoring system for different gas components: NO_x, CO, CO_2 and SO_2. The measuring principle is based on the infrared absorption in the λ=2.5-8 μm wavelength range. The photometer may measure from 1 to 4 components with 1 or 2 beam paths and 1 or 2 receivers in each beam path. The measurement system includes the following parts: analyzer with the central unit, gas sampling unit and sample conditioning unit. The sample conditioning unit incorporates: heated sampling lines, filters, gas pump, gas cooler, condense separator, flow monitor, electric actuated calibration gas valves and calibration gas vessels, all enclosed in a special designed cabinet. Analog output current signals are generated for each of the measured components.

5. DISPERSION SIMULATION

The software module for simulation of the dispersion is based on a Gaussian dispersion based model named SLAB. This computer model was developed by the Lawrence Livermore National Laboratory (USA) in the mid ‘80s and it’s used to model the atmospheric dispersion of denser than air releases. Based on the description of the model presented in the literature [4, 5] a simulation module was developed. This module allows real time prediction, based on meteorological data (the direction and speed of the wind, external temperature, the presence and the rate of precipitations, the degree of cloud coverage) and data about the effluent (rate and temperature of gases that emerge from the source, concentrations in pollutant – gases or dust) by taking into account the shape and height of the source, the concentration gradient at the ground level in the area of the source. These concentration curves allow the prediction of the effects of pollution on humans and also to prevent them in the case of pollutant concentration exceeding the allowed limits. In figure 2 is presented a 3D representation of NO_2 concentration in the vicinity of a source.

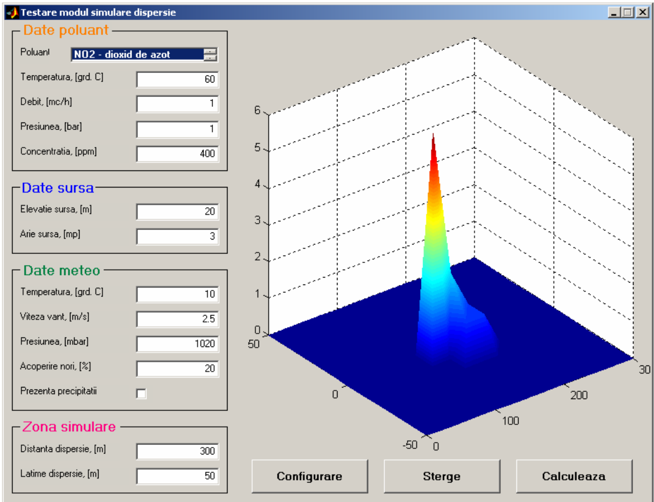


Figure 2. A 3D representation of NO_2 concentration based on the prediction module.

6. GENERAL PRESENTATION OF THE SOFTWARE

The developed software product is referred as a distributed remote measurement system dedicated for monitoring the pollutant emissions from industrial plants using the resources of a programmable automaton, data concentrator computers, data transmitting equipments with specific transducers and wireless communication techniques. The monitoring system has a distributed architecture that includes:

- **Local level** is the level used to communicate and interface with transducers and sensors for pollutant emissions by an acquisition station with programmable automaton. The local stations communicate at this level with a data concentrator computer. In these two units the following functions are implemented:

    - acquisition and concentration of data;
    - modeling of pollutant dispersion;
    - transmission of data to the higher level;

- **Central level** is an automated system for data surveillance and data processing located in the dispatcher unit where the information is received from the local level. At this level event reports and environment balances are synthesized for the monitored locations. In emergency situations the simulation of pollutant dispersion is made and the obtained results are compared with the measured ones. The dispersion simulation takes into account the current local meteorological data.

The coupling between these two functional levels is performed in real time using a dedicated telephone line with high speed modem data transmission equipment.

The monitoring system allows configuring the data acquisition station for larger variety of pollutants and extending the number of data acquisition channels. The systems are extensible also from the hardware or software point of view, allowing additional measurement devices to be easily integrated in the architecture of the system.

7. THE ARCHITECTURE OF THE WIPOL SYSTEM

The software products developed in the frame of this project has the aim to oversee potential industrial air pollutants.

The application includes a series of executable modules that communicate each other in order to achieve the goal of the project.

The architecture selected for this project is based on client-server architecture (figure 3).

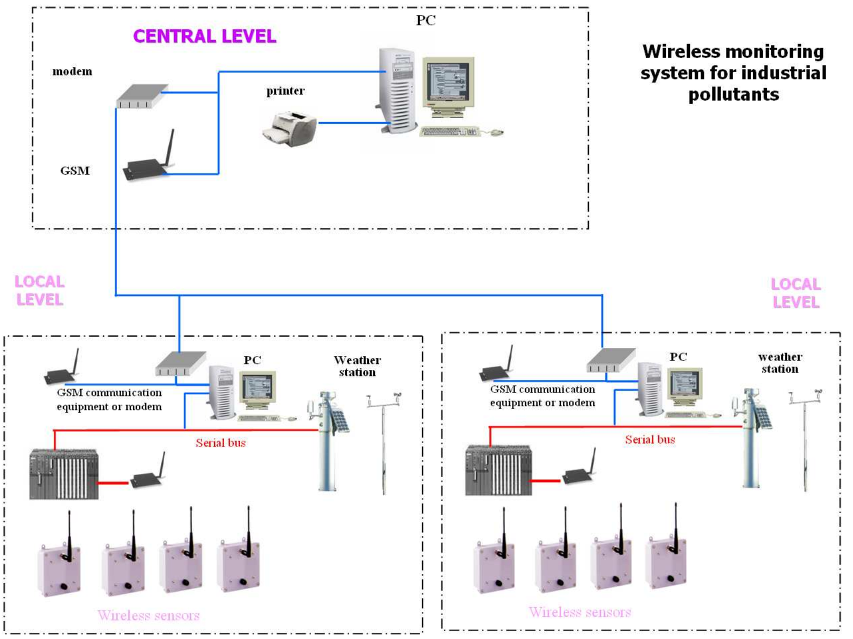


Figure 3. The architecture of the **WIPOL** system.

8. THE WIPOL SOFTWARE APPLICATION

The software application is resident on the computers situated on both hierarchical levels of the tele-assistence system. The **WIPOL** system includes the following executable programs:

- achizsenz – program for data acquisition from sensors – runs on the level of programmable automaton and performs the acquisition of data in engineering units using a configuration table for each sensor attached to it.

- Local dispatcher program consists of two modules:

i. Module for sensors supervision - supravsenz - for data acquisition from the programmable automaton; the data are introduced into the database and the evolution of these parameters are represented under numerical or graphical form on the operator console;

ii. Local dispatcher program - displocal - for primary data processing, generates acquisition reports and graphical representations of data, events report and dispersion maps for the monitored pollutants.

- Central dispatcher program which includes:

i. supravagent - program for supervision of the potentially polluted industrial plant by using a telephone line connection with the economic agent, at preset time intervals or in the case of alarm, uploading the data on the central dispatcher computer for further processing;

ii. central dispatcher program - dispcentral - for processing the acquired data, conditioning the acquisition reports, graphics with the evolution of the parameters, events report and dispersion maps for the monitored pollutants.

The description of the local level programs

The functions of the supervision program at the local dispatcher level are implemented in the application program having two main components:

- application manager - program package at the local dispatcher computer level (figure 4);
- specific program for communication between the local dispatcher computer and the programmable automaton or a wireless RTU (including data packing for transmission, scaling and communication drivers).

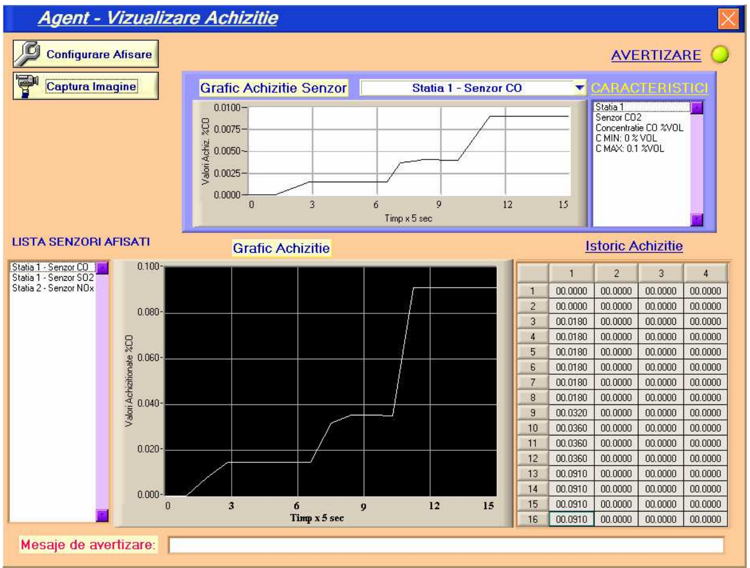


Figure 4. Screen shoot of the manager application at the local dispatcher level.

The program on the local dispatcher level is developed on the principle of virtual instrumentation under the LabWindows CVI (National Instruments) programming environment using the database, statistics and network connectivity components (Enterprise Connectivity Tools) and includes the following functions:

- monitoring of the sensors and transducers network distributed in the location of polluting plants; the monitoring takes place consulting each sensors configuration table and using preset sampling times;

- graphical or tabular acquisition of monitored and calculated parameters; transformation of acquired data in physical units (concentrations, flow rates etc.) according to the associated calibration charts;
- generation of the event reports, recording the moment of time when the event appears and the source of the event;
- application and measurement channels configuration, measurement domain limits setup for sensors and transducers;
- assuring only authorized access to critical operations by a hierarchical system of passwords;
- supervision of alarm limits, the state of the communication with the programmable automaton, the operations made by the exploit personnel determining the alert of the operator by:

  i. acoustic signal – by voice – using the multimedia component of the system;

  ii. visual signal – using overlapping windows techniques that block any other access of the operator until the confirmation of the pop-up message window.

The data transfer to the central level

The transfer is made by modem using a dedicated line introducing the appropriate telephone number in the Connection phone number labeled textbox, with visual indication of the connection status with the central dispatcher computer. The program transfers the files using a modem based communication protocol with data correction algorithm, thus eliminating the transfer errors (figure 5).

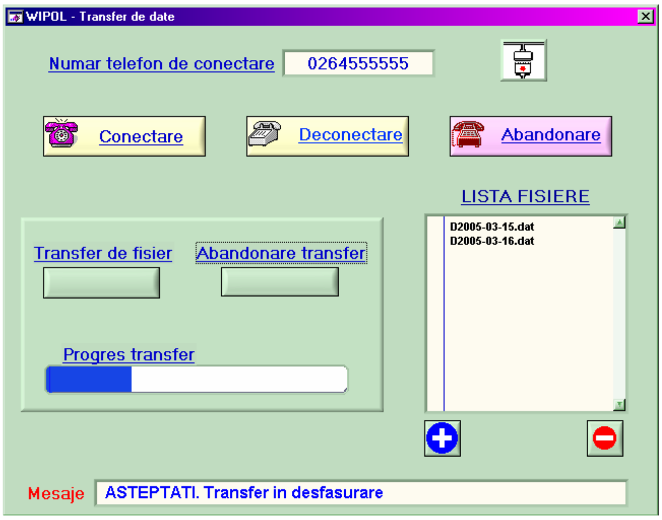
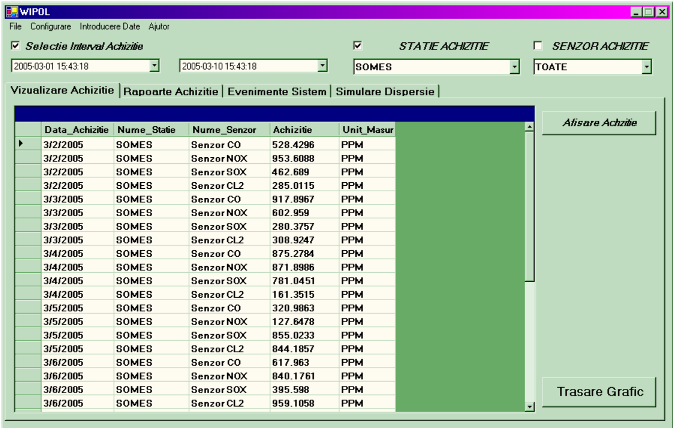


Figure 5. The Data transfer window at the central dispatcher computer.

The functional description of the central level program

In the established geographical area, the local monitoring points are located in the vicinity or on the platform of the potential pollutant industrial plant.

The monitoring equipments, located in the local centre, communicate in real time with the local dispatcher computer (figure 6).



Data_Achizitie	Nume_Statie	Nume_Senzor	Achizitie	Unit_Masur
3/2/2005	SOMES	Senzor CO	528.4296	PPM
3/2/2005	SOMES	Senzor NOX	953.6088	PPM
3/2/2005	SOMES	Senzor SOX	462.689	PPM
3/2/2005	SOMES	Senzor CL2	285.0115	PPM
3/3/2005	SOMES	Senzor CO	917.8967	PPM
3/3/2005	SOMES	Senzor NOX	602.959	PPM
3/3/2005	SOMES	Senzor SOX	280.3757	PPM
3/3/2005	SOMES	Senzor CL2	308.9247	PPM
3/4/2005	SOMES	Senzor CO	875.2784	PPM
3/4/2005	SOMES	Senzor NOX	871.8986	PPM
3/4/2005	SOMES	Senzor SOX	781.0451	PPM
3/4/2005	SOMES	Senzor CL2	161.3515	PPM
3/5/2005	SOMES	Senzor CO	320.9863	PPM
3/5/2005	SOMES	Senzor NOX	127.6478	PPM
3/5/2005	SOMES	Senzor SOX	855.0233	PPM
3/5/2005	SOMES	Senzor CL2	844.1857	PPM
3/6/2005	SOMES	Senzor CO	617.963	PPM
3/6/2005	SOMES	Senzor NOX	840.1761	PPM
3/6/2005	SOMES	Senzor SOX	395.598	PPM
3/6/2005	SOMES	Senzor CL2	959.1058	PPM

Figure 6. Central dispatcher.

The functions of the central level monitoring system are:

- Monitoring of the locally distributed measurement points of the network by uploading the data to the local dispatcher stations at user preset sampling time;
- Generation of the measurement databases by including the acquired measurement data of the local dispatcher stations;
- Generation of graphical representations showing the pollutant concentration and the affected geographical area using the data from measurements and from simulations that are based on the dispersion models and measured meteorological data;
- Presentation in graphical or tabular forms of the acquired and calculated data (figure 7);

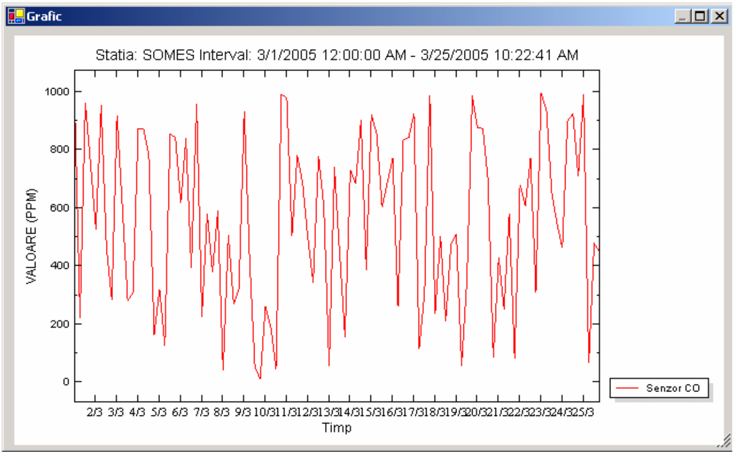


Figure 7. The graphical representation of the CO sensor at the central dispatcher.

- Generation of event and alarm reports, including the moment of time, source and value of the parameters that triggered the event;

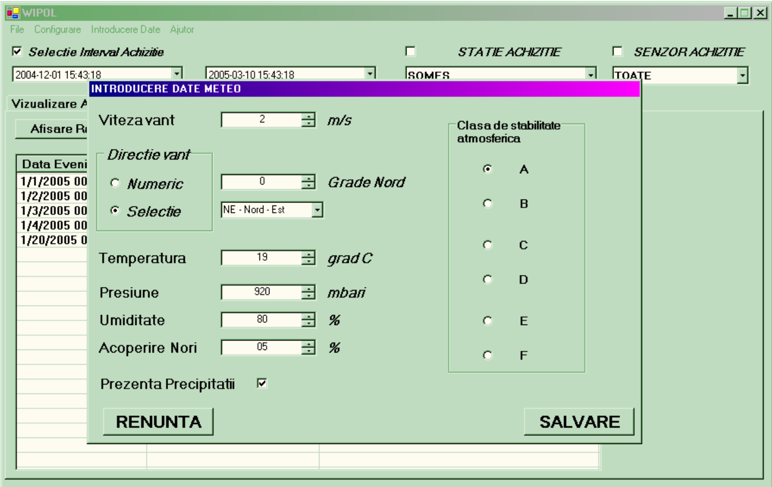


Figure 8. Meteorological data.

- Application configuration, local monitoring station configuration, establishing the risk limits and propagation distances for monitored data taking into account the real meteorological conditions;

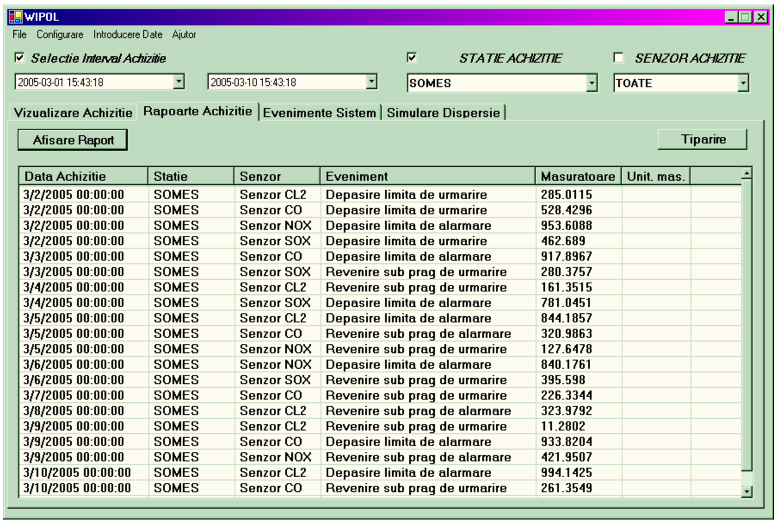


Figure 9. Report window at the central dispatcher.

- Assuring the authorized access to the critical operations by a hierarchical system of passwords;
- Supervision of alarm limits, of the state of the communication with the local monitoring systems, the maneuvers made by the dispatcher personnel, determining an acoustic or visual warning signal generation (figure 9).

9. CONCLUSIONS

Using wireless components a monitoring system for air pollution generated by industrial plants was developed. The main modules of the system are:

- Data acquisition module – using sensors for gases and dust– based on the programmable automaton;
- Concentration prediction module – based on simulation using a mathematical model for dispersion of gases and dust;
- Weather station – to measure the meteorological parameters;
- Client-server system organized on two levels – a local level in charge with: data acquisition, data management and a central level for monitoring multiple pollution sources simultaneously;
- Data transfer module – to transfer the data between the two levels of the system.

The **WIPOL** system is extensible, allowing inclusion of up to 256 monitoring sites. The system is useful in supervising multiple industrial plants releasing pollutant effluents in the air.

REFERENCES

1. *** *Acte Normative privind poluarea mediului* (Legea 137/1995, Ordinul 756/1997, HG 34/2002)
2. R. Z. Tudose, *Ingineria proceselor fizice din industria chimica*, *Vol. I Fenomene de transfer*, Ed. Academiei Romane, Bucuresti, 2000
3. *** DURAG D-R 800 Dust Concentration Monitor, DURAG Industrie Elektronik GmbH & Co KG, Germany
4. D. L. Ermak, *User's manual for SLAB: An atmospheric dispersion model for denser-than-air releases*, Lawrence Livermore National Laboratory, USA, 1990
5. S. Coldea, *Diffusion and dispersion of pollutants in geofluids* (in romanian), Presa Universitară Clujeană, Cluj-Napoca, Romania, 2002