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SYSTEM FOR AUTOMATICALLY PREVENTING THE RAISING OF ASH FROM DEDICATED LANDFILLS•

The paper presents a system for automatic prevention of raising of ashes from dedicated landfills based on a simple mathematical model which has modest entry requirements for meteorological data. Such an approach is efficient enough and enables fast information retrieval, i.e., zones with different concentrations of dust in the air, enabling quick start of counter measures to reduce emissions of ashes into the air. The system hardware consists of an automatic weather station, set of meters that determine moisture of ash, set of remotely managed sprinklers, computers, microprocessor and microcontroller based elements for the local acquisition and management of the executive elements and modules for wireless data transfer. An original software application for the system management has been developed. Within the application there is a module that allows entering of all data necessary to configure the system, as well as data about sensors and sprinklers. Based on the meteorological input data, measured moisture content of the ashes, and on the basis of determined functional dependencies, special software module operates sprinklers for soaking the surfaces from which the ashes is emitted into the air, in order to eliminate these emissions. The system, based on the developed mathematical model, predicts the propagation of ashes through the air, as well as dry and wet deposition, in real-time. The system automatically stores all the data relevant to the future analyses and reporting. The system is designed and implemented as modular and open. A custom developed graphical user interface serves as Man-Machine Interface (MMI). By using the TCP/IP connection it could be easily connected with the other information systems.

Keywords: fly ash; lifting; landfills; thermal power; air pollution.

Thermal power plants that use coal of low calorific value (average of 6 to 10 MJ/kg) [1, 2] generate a large amount of ashes. For example, approximately 3.5 million tons of ashes per year is generated in the thermal power plants “Nikola Tesla” A and B in Obrenovac, Serbia [3]. Upon the completion of combustion in boilers of thermal power plants, flue gases are purified from the particles of fly ashes in electro-filters. Abstracted ashes, collected in funnels under the electro-filters is mixed with the water in 1:10 ratio and transported to the ash landfills.

Raising of dust and ashes from the ash and coal landfills of thermal power plants or from surface mines has a significant impact on the pollution of the environment in the surrounding area. Atmospheric diffusion and dry deposition are the most important mechanisms that influence the concentration of dust in the air and its amount deposited on the ground [4-6]. The amount of ashes and dust that is raised against a surface unit, under certain meteorological conditions and surface characteristics of landfills, is important data that can be used to estimate with how much dust will be covered certain downwind area [7]. The ash landfills are surface sources of pollution, which are active under unfavorable weather conditions. Due to

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unfavorable physical and chemical properties of ashes, eolian erosion of ashes occurs even at low wind speed. Under unfavorable meteorological conditions, dry weather accompanied by strong winds, the dust episodic pollution is a common phenomenon [8, 9]. This problem is especially apparent during the transitional period and in the winter. The problem becomes more serious when the landfills are in the immediate vicinity of settlements and agricultural areas. The effects are most apparent in the areas immediately surrounding the landfills (distance up to 1 km far from landfills).

The ash landfills may cause pollution of water, air and soil. The intensity of impact depends on characteristics of the soil near the ash disposal, as well as physical and chemical properties of disposed ashes [10]. Colloquially it is said that one must take into account the direct and indirect harmful effects. The immediate impacts reflected in permanent loss of quality agricultural land, due to occupation of large areas for ash disposal. For example, the surface of the fly ash landfill of power plants "Nikola Tesla" A and B in Obrenovac is 800 ha, "Kolubara" 50 ha, "Morava" 30 ha and "Kostolac" A and B about 200 ha, making a total of approximately 1080 ha of landfill in Serbia [11]. Opposed to that, indirect degradation of soil (distribution of ashes, acid rain) occurs in much wider areas. Since the ash landfills are located near the villages, due to eolian erosion deposition of ashes occurs on the fertile farmland, which reduces its quality. The most damaging components of ashes that degrade soil are calcium oxide (CaO) and aluminum and iron compounds that often contain phosphorus and arsenic [12]. The deposition of large amounts of ashes over an extended period of time causes increased pH value (acidity), as well as containing other elements such as boron, manganese, arsenic and cadmium, which are also toxic [13-15]. The systems used to reduce raising dust and ashes from landfills face the following problems:

- lack of knowledge on the meteorological conditions that are causing wind erosion;
- lack of functional dependency between meteorological parameters and degree of humidification of dedicated landfill;
- the human element in handling with the damping system.

The use of mathematical models for the calculation of the re-suspension of ashes and dust appears to be more efficient. The models complexity varies for at least two reasons:

- a complex mathematical apparatus that requires the significant computation time and complex physical theories;
- the large number of detailed meteorological input data.

There are several approaches to solving the problem of re-suspension of ashes and dust using the mathematical models based on fluid dynamics [16-21]. Such models have a strong input demand for the meteorological data and other data related to characteristics of the surface covered with dust and ashes, making them inapplicable in our environment.

The authors have developed the mathematical model and approach that is essentially based on relatively simple physics and simple mathematical apparatus [7,22-27]. The originality of this approach lies in the modest input requirements for the meteorological data.

FUNCTIONAL PARTS OF THE SYSTEM

The amount of the ashes that raises from the ash dumps primarily depends on:

- active surface of ash dumps (*i.e.*, areas with ash that can be raised);
- wind speed;
- wind direction;
- the degree of humidity of surface layer of the ashes.

As secondary factors appear:

- air temperature;
- atmospheric pressure;
- relative humidity;
- precipitation;
- global solar radiation

The system is designed to decrease active surface of the ash dumps by increasing the ash humidity. The reduction of the active area is performed by covering of the ash dump with a layer of water [28,29]. Such layer prevents raising of ashes by wind. The thickness of layer should be such that prevents raising of ashes even with the highest winds. The increasing humidity level of ashes also helps in the reduction of ash raising. Clearly, the raising of ash from ash dumps will not occur if the entire surface is covered with the water mirror of sufficient thickness. In the case of large ash dumps, it requires very large amounts of water. Since ash generally isn't homogenous, some parts of the ash dumps may loss "protective" layer of water, due to the increased water absorption. The water from the water mirror evaporating constantly, which also undermines the integrity of the water mirror. On the other hand, under certain meteorological conditions, it is not necessary to form the water mirror. It is sufficient to maintain the required level of the humidity of ashes to prevent the raising from ash dumps.

The system should provide the optimal conditions for minimizing the quantity of ash that raises from the ash dumps by controlling the amount of water that is sprayed over the ash dump and sprinklers schedule, based on [30,31]:

- measurements of the relevant meteorological quantities in real-time;
- measuring the humidity of the surface layer of ashes in real-time;
- the semi-empirical algorithm.

The amount of water sprayed over the ash dumps should be minimal provided that it results in maximum reduction of the emissions of fly ash, and the dynamics and working schedule of the sprinklers should also serve the same purpose.

This concept defined the key elements of the system:

- the device for automatic measurement of meteorological parameters;
- the device for measuring humidity of the surface layer of ash;
- the device to automate the management of the executive elements of the system;
- the main module;
- the devices for wireless data transfer;
- the computer that runs specially developed control program [32].

The main advantage of the system is that it is fully automated, and controls the emissions of ashes on the real-time bases.

The control system is distributed, consisted of two parts:

- the field part (located at ash dumps);
- the control center;

The field part consists of:

- the device for measuring of the meteorological parameters (Weather Transmitter WXT510, Vaisala Company, as shown in Figure 1;
- the acquisition unit, (marked as AM1 in Figure 1) that allows data acquisition from the temperature sensors (Pt1000) and the solar radiation balance meter (Radiation Balance Meter);
- one or more devices for management of the executive elements of the system, (marked as IM1 in Figure 1) that can manage up to 8 executive elements;
- one or more devices for automatic measurement of the humidity of ashes, (marked as SM1 in Figure 1) that can perform the acquisition from up to 8 sensors;
- one or more main units (in Figure 1 marked as UM1).

One main unit can manage up to 6 devices. This means that the first main unit, in addition to a device for measuring of the meteorological parameters (which occupies two communication ports) can manage, for example, two more devices for the automation of the management of executive elements and two devices for automatic measurement of humidity of ashes. Depending on the size of the ash dump, to manage the other devices for automation of management of the executive elements, and devices for automatic measuring of the humidity of ash, the appropriate number of main units should be added.

The application software runs on a PC computer in the control Centre (PC in Figure 1). The computer can be connected with other computers, either locally or remote, using the standard TCP/IP communication protocol.

The communication unit that enables GSM/GPRS communication with the main units at the ash dumps is situated in the control Centre (marked with CM1 in Figure 1).

Communications and data transfer inside the system

In certain time intervals (defined upon setting up the system), the control program generates messages and sequentially calls all the main units located on ash dumps. In the case that the main unit does not send back the correct response, the appropriate alarm will be generated.

When the main unit answers correctly, the control program sends a request to activate the device for measuring the meteorological parameters. As a response, the main unit forwards the values obtained by measurement. This data, along with the associated time marker are automatically saved upon completion of the data transfer. If the devices did not provide the correct set of data, the appropriate alarm will be generated. A timestamp will be attached to every alarm generated, and then it will be automatically saved.

In the next step, a request to activate the device for automatic measurement of the humidity of ashes is being sent to the main unit, and as a response, the values obtained by measurement are being forwarded to the Centre. If the devices did not send back correct response, the control program generates the appropriate alarm. If the main unit is connected to the multiple devices for automatic measuring of the humidity of ash, the main unit sequentially calls them in order defined upon the configuration of the system.

Finally, the main unit sends message to the command device for automation of management of the executive elements (electro-valves). In the case when the main unit is connected to the multiple devices for the electro-valves control, sending order is defined upon the configuration of the system. After the realization of received commands, the device for

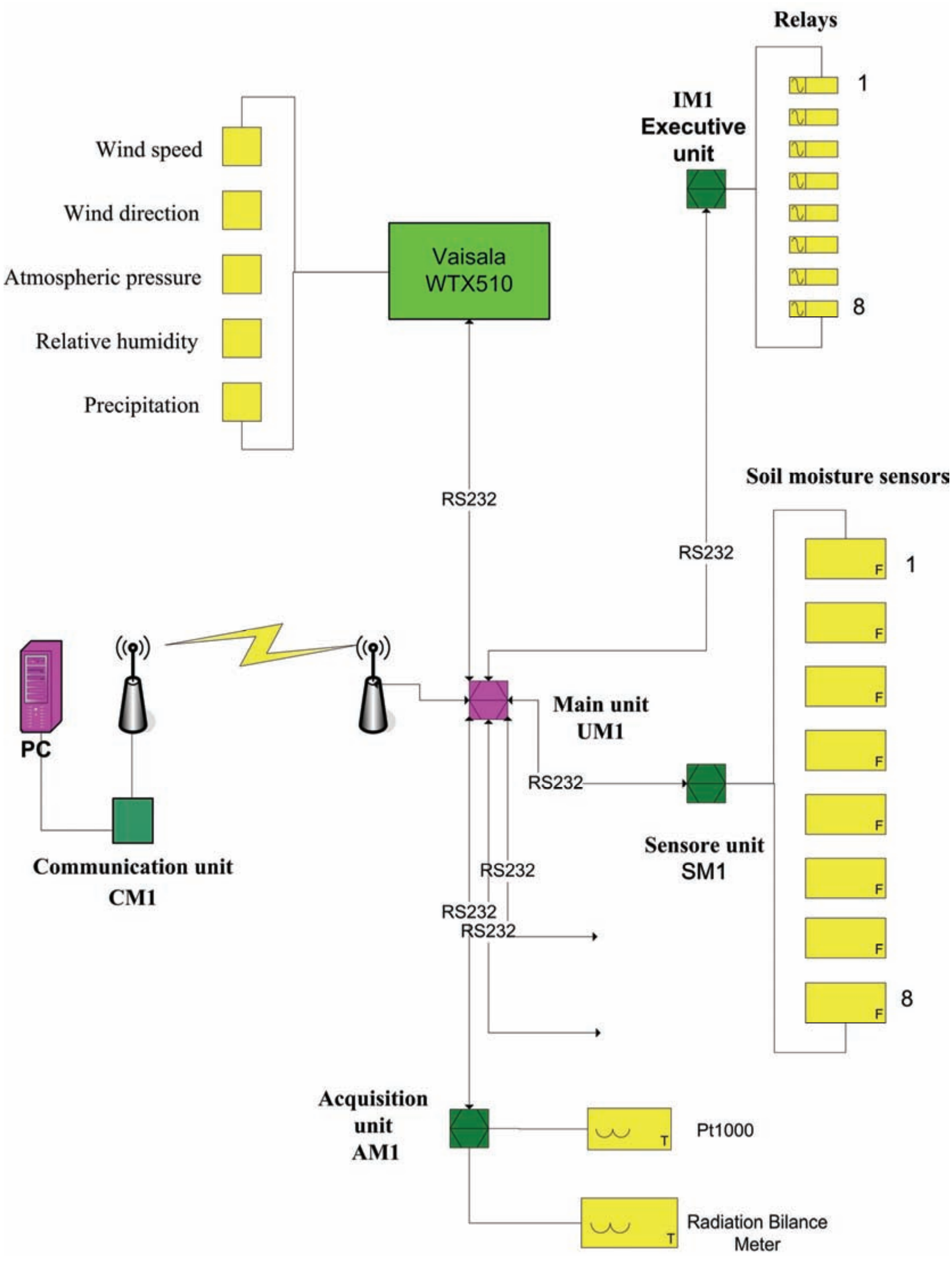

Figure 1. Block diagram of the system.

automation management of the electro-valves sends a return massage with the information about each electro-valve.

System hardware

Device for automatic measuring of the meteorological parameters

The device for automatic measurement of the meteorological parameters, which are essential for defining the working criterion of the executive elements of the system, consists of a set of sensors that measure meteorological parameters and unit for the automatic acquisition of the measured values in real time.

A set of sensors that measure meteorological parameters is defined based on the meteorological values used as input data for the mathematical model, and includes sensors that measure: wind speed, wind direction, air temperature (at two levels), atmospheric pressure, relative humidity, global solar radiation and the amount of precipitation.

A Vaisala weather transmitter WXT510 (marked with WXT510 in Figure 1) is used for measuring wind speed and direction, atmospheric pressure, relative humidity and air temperature as well as precipitation. Wind direction is measured in the range from 0 to 360° with output resolution of 1° and accuracy ±3.0°. Wind speed is measured in the range from 0 to 60 m/s with an output resolution of 0.1 m/s and accuracy of ±3% (±5% for wind speeds higher than 35 m/s). Measurement range of atmospheric pressure is from 600 to 1100 hPa with output resolution of ±1 hPa and accuracy of ±0.5 hPa. Relative humidity is measured in the range from 0 to 100%, with an output resolution of ±0.1% and accuracy of ±3% (±5% for the range of 90 to 100%). Air temperature is measured in the range from -52 to 60 °C, with an output resolution of 0.1 °C and accuracy ±0.3 °C. Precipitation is measured on an area of 60 cm^2 with an output resolution of 0.01 mm and field accuracy for daily accumulation of 5%.

The WXT510 is connected to the main unit (marked as UM1 in Figure 1) *via* an RS232 serial interface and via main model to the computer at the Centre. Upon receiving the command, the WTX510 sends a message containing the measured values of specified parameters, for the defined period of measurement (average values).

The device for automatic measurement the meteorological parameters includes additional air temperature meter, located 1 m above the ground. The meter uses a Pt1000 sensor connected to an acquisition unit, which is marked with AM1 in the Figure 1. To measure the solar radiation balance, a Radiation Balance meter series 1612 was used, from Lambrecht Company, that measures total radiation balance within range from 0.3 to 60 μm, with the sensitivity of approx. 2 mV/(J cm^{-2} min^{-1}). This balance meter is also connected to an acquisition unit AM1. The AM1 unit is an electronic set controlled by the Microchip microcontroller 18F2520. The unit has 10 bit A/D converter with 8 inputs, 8 digital outputs and one serial port. *Via* serial port it transmits data obtained by measurement with Pt1000 and Radiation Balance meter to the main unit (UM1).

Device for automation of management of the executive elements of the system

This device is used to start and stop watering the ash. After receiving the command, the device interprets its contents, and based on that information generates the appropriate signals for relays that control powering of the electro-valves. This device enables control of up to 8 electro-valves. Each valve has its own identification number, and the message that comes from the centre to this device is composed of pairs formed by valve identification number and the numbers 1 or 0 (1 for the signal that opens the valve, and 0 for a signal that closes the valve).

The device uses the Microchip microcontroller 18F2520. Serial port is used for communication with the main unit (UM1).

Device for automatic measuring of moisture in the ash

The device for automatic measurement of moisture of the surface layer of ashes was designed to respond to a “call” from the Centre with a message containing a set of measured values of humidity of ashes (since, due to the size ash dumps, multiple sensors are used). The data is used as a control value for the model for evaluation when sprinklers should be turned on or off.

This device (marked with SM1, in Figure 1) also uses Microchip microcontroller 18F2520. The device allows measurements from 8 sensors for measuring humidity of the surface layer of ashes. The sensors are of the capacitive type and have a measurement range from 0 to 100% with the margin of error less than 10%, and connected to the ports for the analog/digital conversion. Since the humidity of ashes is the parameter that changes slowly, the device performs measurements every 10 min.

Main unit

The main unit (marked with UM1, in Figure 1) performs several tasks:

- the communications with device for automatic measurement of the meteorological parameters, device (devices) for measurement of humidity of ashes and device (devices) for the automation of management of the executive elements of the system;

- by using the package of the GSM network and GPRS protocols, corporate access with fixed IP addresses, the main unit enables wireless connection with the computer at the control Centre. This approach enables the formation of the local network with no access to the public Internet network, which provides an additional security whilst transferring data. The connection status is checked on every minute, and the data transfer is performed by using the specially developed algorithm.

The device is controlled by the Microchip microcontroller 18F2525. The device has six Microchip 16F690 microcontrollers for control the RS232 serial communication with devices located on ash dumps. The device contains a Telit GM862 communication module that provides quad-band GSM/GPRS modem functionality for the connection with the Centre.

Communication unit in the Centre

The communication unit in the Centre (marked with CM1 in Figure 1) is a device that together with the main unit (one or more) provides wireless transmission of data, using the GSM network and GPRS protocol. The device is controlled by a Microchip microcontroller 18F2525 and uses the Telit GM862 communication module that provides quad-band GSM/ /GPRS modem functionality for the connection with the main units.

PC Workstation in the Centre

PC Workstation in the Centre is a classic desktop PC running under Microsoft Windows XP, SP3. The minimum hardware requirements for the PC are as follows: Intel Pentium 4 CPU 2.40 GHz, 1 GB of RAM and 40 GB hard disk.

Application software

The entire system is operated from the PC workstation at the Centre. The control program is specially developed and implemented as modular and open, it contains two types of software:

- modules that operate automatically;

- modules that starts upon entering the appropriate commands.

The most significant software modules that operate automatically are as follows:

- module for commanding control unit at the site of ash dumps;

- modules for automatic reception, processing and storage of the measured values (meteorological parameters, and ash humidity);

- module for sending massages to devices for automation of management of the executive;

- modules for the entire system components monitoring;

- module for networking and communication;

- graphical user interface.

The most significant modules that start upon the entering the appropriate commands are as follows:

- module for defining the system configuration;

- module for defining parameters important for the operation of the system (time intervals, limit values for the meteorological parameters and humidity of ash, etc.);

- modules for displaying of measured values in real-time or for a selected date and time;

- modules for automatically generation of daily, monthly and annual reports;

- module that allows operation and control of the system of passwords for operators.

A special part of the control program software is the unit that, based on the input data and mathematical model, enables the evaluation of ash dispersion.

The control program is written using Microsoft Visual Studio 6.0, with the exception of the unit for the ash dispersion assessment, which is written in Compaq Visual Fortran 6.0. The reports and summaries use Microsoft Word and Microsoft Excel, from the Microsoft Office 2003 package.

Graphical user interface

Graphical User Interface (GUI) was chosen for the Man-Machine Interface (MMI). Figure 2 shows the layout of the main menu, which is the main GUI screen.

Starting of the individual software units is accomplished by clicking the appropriate button in the main menu. The buttons are grouped into the four groups:

- The buttons that allow real-time monitoring, as shown in Figure 2. That group is in the first box from the top and marked with "*Monitoring u realnom vremenu*". This includes buttons, "Tent-A", "Tent-B" - to show condition on ash dumps, "Meteo" - to display the measured meteorological values, "*Imisija* PM10" - to show PM_{10} concentration levels, "*prostiranje*" - to display the propagation of ash cloud that comes from the ash dump and "*Rad sistema*" - to display the status of all the elements of the system.

- The buttons that enable the obtaining of reviews for the selected date and time. In Figure 2 this group is in the second box from the top and marked with "ANALIZA ISTORIJSKIH PODATAKA."

- The buttons that enable obtaining of daily, monthly and annual reports. In Figure 2 the group is marked "*Izveštaji*". This includes buttons, "*Mesečni*" and "*Godišnji*" in the sub-frames "Tent-A" and "Tent-B" - for the monthly and annual reports on ash dumps condition; buttons "*Mesečni*" and "*Godišnji*" in the sub-frame "Meteo" - to obtain the monthly and annual reports of the meteorological values; buttons "*Mesečni*" and "*Godišnji*" in the sub-frame "*Imisija* PM10" – for obtaining the monthly and annual reports of the PM_{10} concentration levels, buttons "*Mesečni*" and "*Godišnji*" in the sub-frame "*Rad senzora*" - for obtaining monthly and annual reports on the work of the sensors and buttons "*Mesečni*" and "*Godišnji*" in the sub-frame "*Rad prskalica*" - for obtaining relevant reports on the work of the sprinklers.

- The buttons, grouped in frame marked as "Sistem" in Figure 2, that allow entering the sensor and sprinklers allocation on ash dumps (buttons marked "Tent-A" and "Tent-B" in the sub-frame, "*Senzori i prskalice*"), configure the system (the "Konfig" button), define the boundary condition for parameters

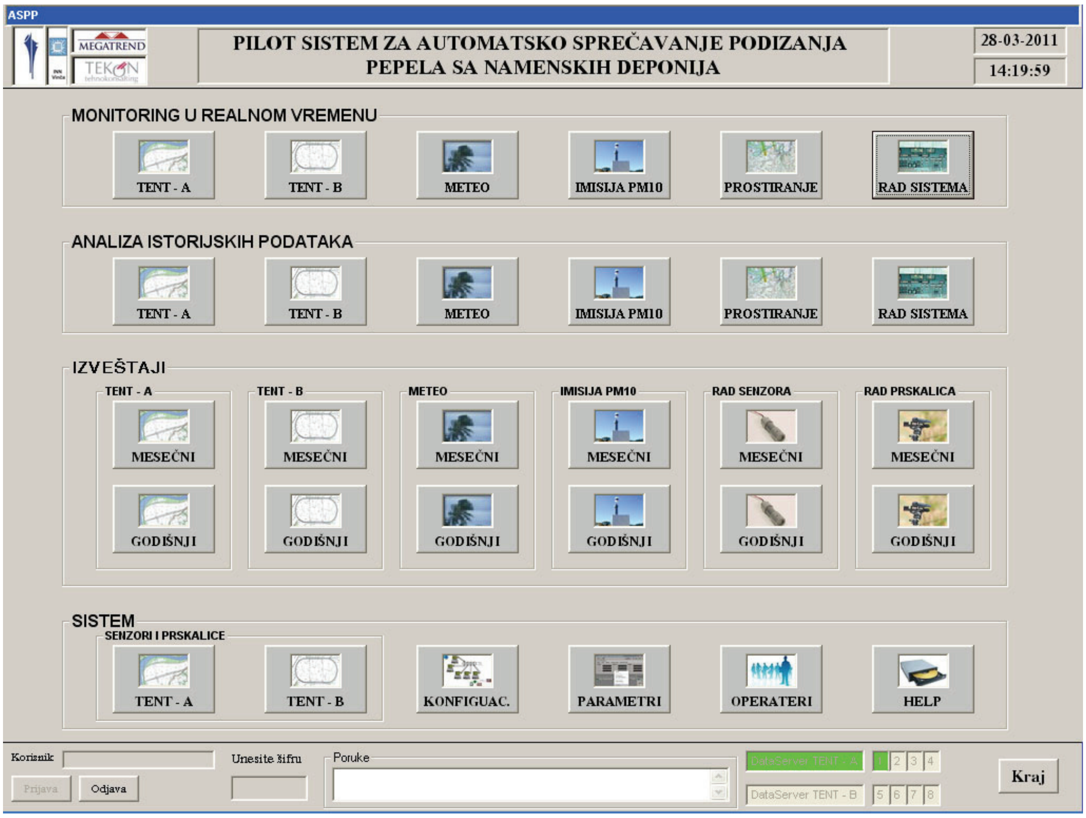

Figure 2. Control program main menu.

(button "*Parametri*"), entering and/or changing information about the users and their passwords (button "*Operateri*"), and start Help.

The GUI allows data to be displayed in both graphic and tabular form. Figures 3-5 show examples of the GUI screens used to display data received in real-time. Figures 3 and 4 show the meteorological data, whilst Figure 5 shows the condition on the ash dumps. Figure 3 presents an example of the screen (with simulated data) that allows graphical presentation of the meteorological data obtained by "measuring" in real-time. One can get graphical display of the results obtained by measurements of the automatic weather stations located in the Tent-A (clicking the tab "*AMS 1 i 2 podaci sa Data Servera na Tent-A*") or a graphical display of the meteorological values obtained by using a device for the automatic measurement of the meteorological parameters at the location of ash dumps (click on the tab "*Lokalna AMS*").

Figure 5 shows an example of the conditions (simulation) on ash dumps in real-time, the sensors and the sprinklers arrangement together with the sprayers that currently operate.

The geographical map with a grid of 100 m×100 m is used for viewing the ash dumps. Three cross-sections of ash dump, with corresponding data are shown below the map. The green color on the map indicates part of ash dump that's not active because it is covered with grass. The blue color of the squares in a grid on ash dump indicates that the part is covered with water mirror, *i.e.*, that the humidity of ashes is sufficient to prevent the re-suspension. The red circles mark sensors for measuring the humidity of the surface layer of ash, and the sprinklers are marked with the little blue square. The sprinklers currently working are marked with the little filled blue square. Clicking the tab "*Senzori*" activates display with the sensors arrangement on the ash dumps, and a table with the sensor details, their coordinates, for which field in the grid the measurement of each sensor is representative, and the current measured value of the humidity of the surface layer of ash. By clicking the tab "*Prskalice*", a layout of the sprinklers on ash dumps can be obtained, *i.e.*, a table with details on the sprinklers, their coordinates and information whether the sprinkler is active or not.

Software for the real-time assessment of the ash dispersion

By using all the data received, this software calculates and displays the ash dispersion in real-time. The different concentrations of ash in the atmosphere are presented on the ashes disposal map with the appropriate colors. The numerical model generates a

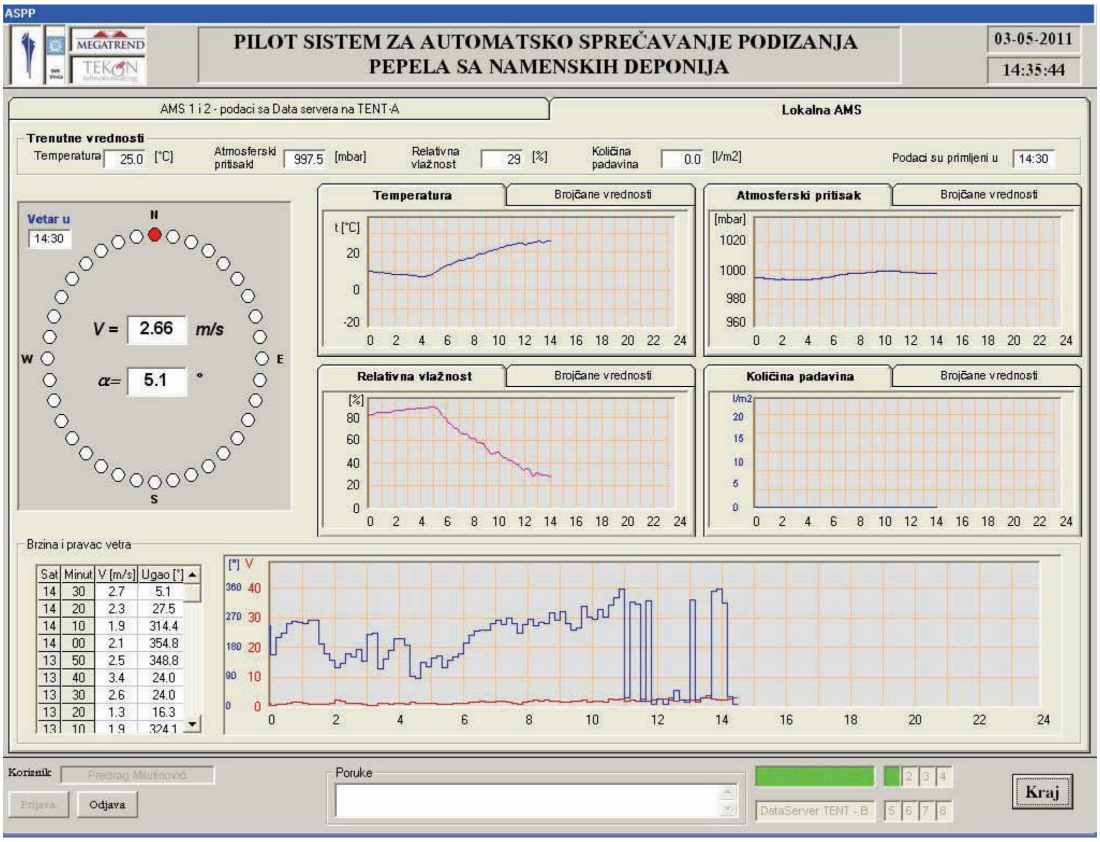

Figure 3. Display of measured meteorological parameters in graphical form.

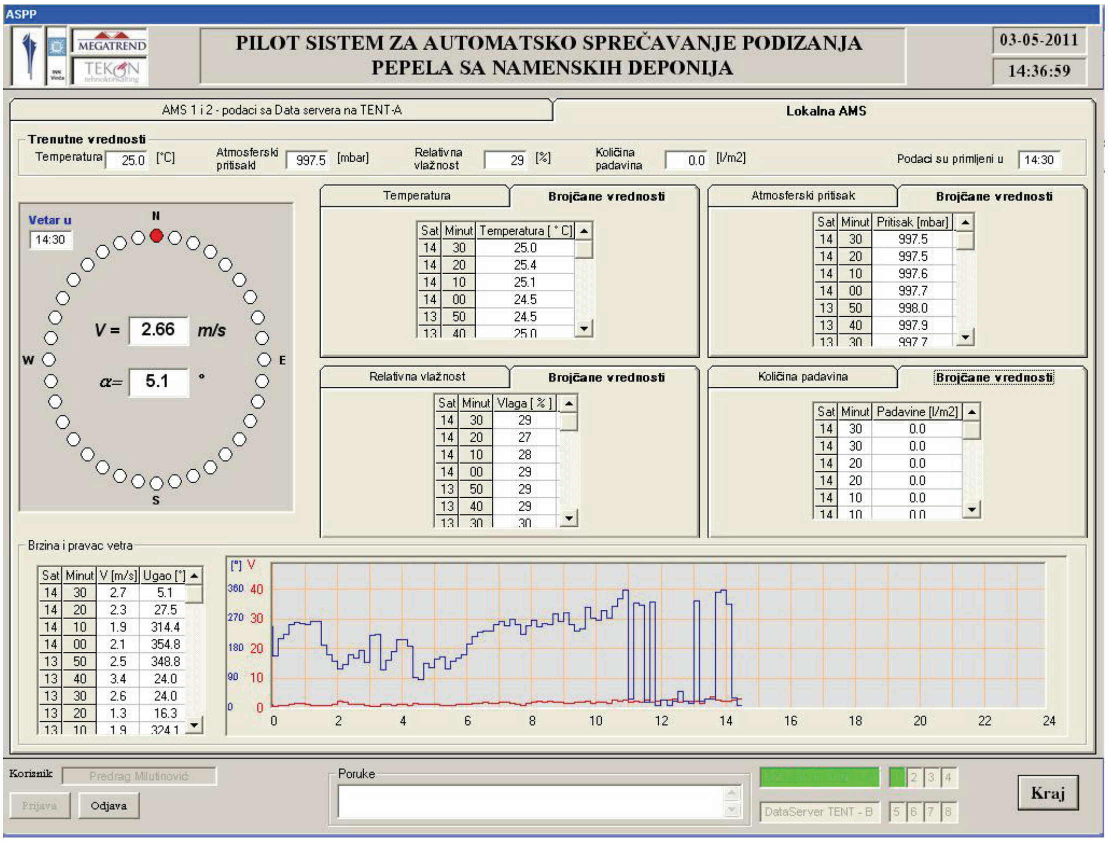

Figure 4. Display of measured meteorological parameters in numerical form.

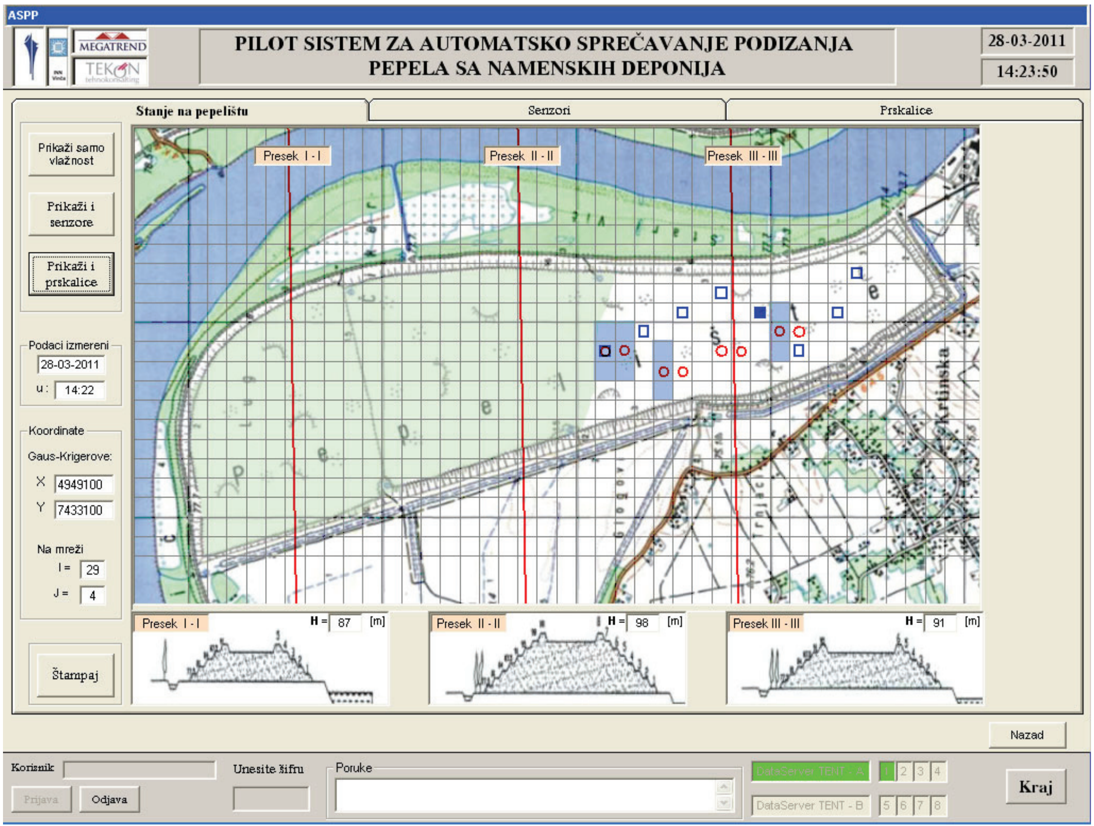

Figure 5. Synoptic display of conditions at the ash dump.

network of points in the grid of 100 m×100 m, and based on this network "clouds" of different concentrations are drawn on the map.

Equation (1) describes propagation of the ashes through the lower boundary layer of the atmosphere [7, 21, 33 and 34]:

$$C(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z u}\exp(-\frac{1}{2}\frac{y^2}{\sigma_y^2})\times \\ \times[\exp(-\frac{1}{2}\frac{(y-H)^2}{\sigma_y^2})+\exp(-\frac{1}{2}\frac{(y+H)^2}{\sigma_z^2})] \qquad (1)$$

where $C(x, y, z)$ is the concentration at grid point (x,y,z) (μ/m^3), y is lateral (crosswind) distance from the plume axis (m), z is height of the receptor above ground (m), Q is the source strength (kg/h), H is effective height of source emission (m), σ_y *and* σ_z are diffusion coefficients in y and z directions, respectively, (m) and u is average wind speed (m/s).

The model can operate in diagnosis or prognosis mode. Raising of the plume/cloud is calculated by using the Briggs model and wind power law [35]. The model takes into account the topography and dry and wet deposition of pollutants in accordance with the Vitek recommendation [36]. Plume/cloud occurs with the appearance of wind. The wind speed and direction are measured with the automated weather station located on ash dumps, thus the model is able to predict the ash concentration distribution and its change in accordance with wind and turbulence. The model could be applied for distances up to 30 km far from the ash dumps. The mathematical model was developed according to the recommendations prescribed by:

- US EPA (United States Environmental Protection Agency),
- EEA (European Environment Agency),
- USNRC (United States Nuclear Regulatory Commission) and
- WMO (World Meteorological Organization).

Figure 6 shows the dispersion of ash from the ash dumps of thermal power plants Tent-A and Tent-B, over the territory of the Municipality Obrenovac, Serbia.

The geographic map of the area is used as the background. The clouds showing estimated concentration of ash in the air are colored according to the scale shown on the left side of the screen. The numeric value of maximal concentration in the entire area is shown in the corresponding field on the right side of the screen. By the clicking on the specific place on the map, a field that contain value of concentration at that point appears, together with the geo-

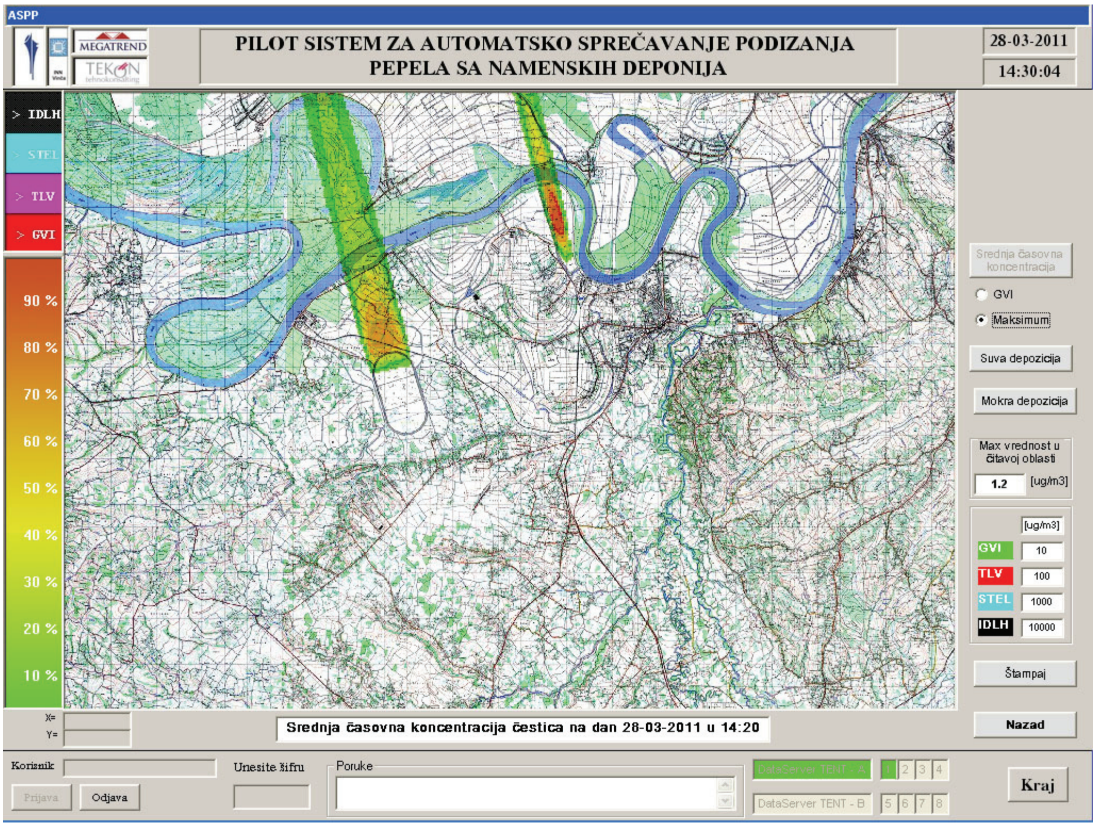

Figure 6. Assessment of ash concentration dispersion.

graphic coordinates of the selected point (fields in the lower left corner of the screen marked as “X” and “Y”).

This software also enables obtaining the dry and wet deposition and their graphic display. By clicking the corresponding button, "Suva depozicija" to display the dry deposition, or "Mokra depozicija" to display the wet deposition. Naturally, like all the reviews and reports, this review may also be obtained in printed form upon the request.

CONCLUSION

During weather conditions with strong wind episodes, coal and ash dumps can be large sources of air pollution with particulate matter. There are several approaches in solving of this problem in the world. This paper presents an original system for automatic prevention of rising of ash. Its originality is reflected in the design of hardware and development of custom-made software for the system management. It is important to note that relatively simple mathematical model for the real-time evaluation of the ash dispersion is implemented. Its simplicity lies in the assumption of Gaussian distribution of the concentration of pollutants (ashes and dust) in the contaminated cloud, which has simplified the mathematical calculations. This simplified but efficient approach enables fast information retrieval, *i.e.*, zones with the different concentrations of dust/ashes in the air, and the amounts deposited on the ground per unit area. By applying this model, results can be obtained much faster compared with the complex models. The presented system is based on the established dependency of causes (in this case meteorological conditions) and consequences (ash emissions), which enables quick application of adequate counter-measures to reduce the harmful effects on the environment at small distances downwind from the ash dump. The system could be a useful tool for air quality management, because the information is obtained in real time.

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REFERENCES

[1] Statistical Office of the Republic of Serbia, Energy Balances of the Republic of Serbia for the year 2008.

[2] Electric Power Industry of Serbia (EPS), Technical Report 2010, http://www.eps.rs/Eng/Tehnicki%20Izvestaji/ /TEH_Godisnjak2010_en_web.pdf

[3] Electric Power of Serbia (EPS), Environment protection. http://www.eps.rs/Eng/Documents/EPS%20Environment %20protection.pdf

[4] S.M. Fan, L.W. Horowitz, H. Levy II, W.J. Moxim, J. Geophys. Res. **31** (2004) L02104

[5] S. Nickovic, G. Kallos, A. Papadopulos, O. Kakaliagou, J. Geophys. Res. **106** (2001) 113-129

[6] M. Ishizuka, M. Mikami, J. Leys, Y. Yamada, S. Heidenreich, Y. Shao, G. H. McTainsh, J. Geophys. Res. **113** (2008) D24212

[7] Z. Gršić, Research fields of air pollution concentrations using generalized Gaussian dispersion model, Ph.D Thesis, University of Niš, 2011

[8] J.O.Eckert Jr, Q. Guo, J. Hazard. Mater. **59** (1998) 55-93

[9] M.R. Raupach, J.F. Leys, Aust. J. Soil Res. **28** (1990) 177-191

[10] J.K. Tishmack, in Proceedings of Coal Combustion By-Products Associated with Coal Mining - Interactive Forum, 199), pp. 13-20

[11] Studija opravdanosti sa idejnim projektom i studijom o proceni uticaja na životnu sredinu rekonstrukcije sistema za transport i deponovanje pepela i šljake TE Nikola Tesla A (blokovi A1-A6), Energoprojekt – ENTEL, 2010

[12] United Nations Environmental Programme (UNEP) Interim guidelines on hazard characteristic H13 of Annex III to the Basel Convention. Geneva: UNEP 2004. UNEP/ /CHW.7/11/Add

[13] A.S. Meawad, D.Y. Bojinova, Y.G. Pelovski, Waste Manage. **30** (2010) 2548-2559

[14] P. Asokan, M. Saxena, A. Aparna, S.R. Asoletar, Waste Manage. Res. **22** (2004) 265-275

[15] L.B. Clarke, Fuel **72** (1993) 731-736

[16] P. Goyal, Environ. Modeling Software **19**(4) (2004) 383-390

[17] Y. Shao, A.N. Li, Boundary-Layer Meteorol. **91** (1999) 199-225

[18] H. Lu, Y. Shao, Environ. Modelling Software **16** (2001) 233-249

[19] H. Lu, Y. Shao, J. Geophys. Res. **104** (1999) 827-842

[20] Y. Shao, Boundary-Layer Meteorol. **115** (2005) 319-338

[21] P. Goyal, M.P. Singh, A. Gulati, Atmos. Environ. **30**(7) (1996) 1159-1166

[22] Z.Gršić, M.Jovašević-Stojanović, P.Milutinović, M. Popović, in 25th NATO/CCMS International Technical Meetings on Air Pollution Modelling and Its Application, Belgium, 2001, p. 509

[23] Z. Grsić, P. Milutinović, M. Jovasević-Stojanović, M. Popović, in Air Pollution Modeling and its Application, XV, Kluwer Academic/Plenum Publishers, 2002, pp. 509-511

[24] Z. Grsić, P. Milutinović, M. Jovasević-Stojanović, D. Dramlić, M. Popović, in 26th ATO/CCMS International Technical Meeting on Air Pollution Modeling and its Application, Preprints, Istanbul, 2003, pp. 85-91

[25] Z. Gršić, P. Milutinović, Lj. Živković, D. Dramlić, M. Popović, in 5th International Conference of Balkan Environmental Association (B.E.N.A) on Transboundary Pollution, Yugoslavia, Belgrade, 2002, p. 72

[26] Z. Gršić, P. Milutinović, Lj. Živković, D. Dramlić, M. Popović, in 5th International Conference of Balkan Environmental Association (B.E.N.A) on Transboundary Pollution, Yugoslavia, Belgrade, 2002, p. 84

[27] Z. Gršić, P. Milutinović, M. Jovasevic-Stojanović, D. Dramlić, M. Popović, in Air Pollution Modeling and its Application XVI, Edited by Carlos Borrego and Selahattin Incecik, Kluwer Academic/Plenum Publishers, New York, 2004, pp. 127-134

[28] Z. Gršić, P. Milutinović, B. Rajković, D. Dramlić, Z. Velikic, S. Dramlic, Chem. Ind. Chem. Eng. Q. **16**(3) (2010) 243-249

[29] Z. Grsic, P. Milutinovic, D. Dramlic, Z. Velikic , S. Dramlic, in 2nd International Workshop, Particulate Matter: Research and Management Mećavnik, Mokra Gora, Serbia, 2009, pp. 73-79

[30] Z.J. Grsic, P.S. Milutinovic, LJ. Zivkovic, D.M. Dramlic, M.M. Popovic, in Fifth General Conference of the Balkan Physical Union BPU-5, Vrnjačka Banja, Serbia and Montenegro, 2003, pp. 1533-1536

[31] Z. Grsic, M. Jovasevic-Stojanovic, P. Milutinovic, D. Dramlic, in Proceedings of the 10th International Conference on Harmonization within Atmospheric Dispersion Modeling for Regulatory Purposes, Cyprus, 2005, pp. 350-355

[32] D. Dramlić, P. Milutinović, Z. Gršić, D. Joksimović, Z. Velikić, S. Dramlić, B. Vulević, in Book of papers of 14th Symposium on Thermal Science and Engineering of Serbia, Soko Banja, 2009, pp. 819-824

[33] B. Rajkovic, I. Arsenic, Z. Grsic, in Fluid Mechanics of Environmental Interfaces, C. Gualtieri, D.T. Mihailovic, Eds., Taylor & Francis Ltd., 2008, pp. 17-48

[34] Y. Shao, M. Raupach, J. Geophys. Res. **98** (1993) 12719-12726

[35] G.A. Briggs, Plume rise predictions, in: Lectures on Air pollution and Environmental Impact Analyses, Workshop Proceedings, American Meteorology Society, Boston, MA, 1975, pp. 58-111

[36] P. Wittek, A Survey of Atmospheric Dispersion Models Applicable to Risk Studies for Nuclear Facilities in Complex Terrain, KfK-3870, Karlsruhe, Germany, 1985.

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STRUČNI RAD

SISTEM ZA AUTOMATSKO SPREČAVANJE PODIZANJA PEPELA SA NAMENSKIH DEPONIJA

U radu je prezentiran sistem za automatsko sprečavanje podizanja pepela sa namenskih deponija, baziran na jednostavnom matematičkom modelu koji ima skromne zahteve za ulaznim meteorološkim podacima. Takav pristup je dovoljno efikasan i omogućava brzo dobijanje podataka, odnosno zona sa različitim koncentracijama prašine u vazduhu, što omogućava brzo pokretanje kontra mera radi smanjivanja emisije pepela u vazduh. Hardver sistema, pored računara, mikroprocesorskih elemenata za lokalnu akviziciju i upravljanje izvršnim elementima i sistema za bežžični prenos podataka, čine i automatska meteorološka stanica, skup merača za određivanje vlažnosti pepela i skup prskalica kojima se upravlja daljinski. Razvijen je originalan namenski softver za upravljanje sistemom. U okviru softvera postoji modul koji omogućava da se unesu svi podaci neophodni za konfigurisanje sitema, kao i podaci o senzorima i prskalicama. Poseban softverski modul na osnovu ulaznih meteoroloških podataka i podataka o izmerenoj vlažnosti pepela, a na osnovu utvrđenih funkcionalnih zavisnosti, upravlja prskalicama za kvašenje vodom površina sa kojih se emituje pepeo u vazduh, u cilju eliminisanja te emisije. Sistem poseduje i softverski modul koji, na osnovu razvijenog matematičkog modela, omogućava da se, u realnom vremenu, izvrši predikcija rasprostiranja pepela u vazduhu, kao i suve i vlažne depozicije. Svi podaci se automatski memorišu što omogućava da se izvrši rekonstrukcija situacija za izabrani datum i izabrano vreme. Sistem je koncipiran i realizovan kao modularan i otvoren. Komunikacija čoveka i sistema je ostvarena korišćenjem namenski razvijenog grafičkog korisničkog interfejsa. Pomoću TCP/IP veza moguće je ovaj sistem povezati sa drugim informacionim sistemima radi razmene podataka.

Ključne reči: leteći pepeo, podizanje, deponije, termoelektrane, zagađenje vazduha.