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MODELING THE DISPERSION OF SO_2 IN ZENICA VALLEY

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ABSTRACT: In order to determine the emissions from individual point sources in the total amount of sulfur dioxide immission in a particular area of Zenica valley, executive modeling of air pollution of sulfur dioxide from industrial heating plants where the dominant burning brown coal and gas technology with higher sulfur content, and natural gas in small quantities. Analyzed the emission of sulfur dioxide plume from the chimney of industrial power plants. When modeling using the standard Gaussian model of dispersion of sulfur dioxide by a series of current measurement point imission Tetovo, located near the industrial power plants. At the specified measurement point was performed calibration model and defines the level of participation of SO2 emitted from the chimney power plants with a total SO2 immission and air pollution. This paper describes the establishment of an automated method of collecting data on emissions and meteorological data and conducted an evaluation visit of the obtained values for the selected period of monitoring air quality based on the analysis of average values of measured emissions and meteorological data, with appropriate assumptions and simplifications. The application of computational models is particularly important for industrial and urban areas, such as Zenica, due to excessive air pollution and the occurrence of episodes of high air pollution, because it allows timely detection exceeding the limit values of immission and implementation of emergency measures to reduce emissions to protect air and public health .
KEYWORDS: dispersion modeling of SO_2, emission, imission, air quality monitoring

INTRODUCTION - EMISSIONS OF SULFUR DIOXIDE

Sulphur dioxide (SO_2) is one of the most common air pollutants. He comes to the environment from volcanoes and industrial processes, particularly combustion of fossil fuels loaded with sulfur compounds. It is a colorless gas, the characteristic sharp odor, is heavier than air, which at elevated concentrations in the air is detrimental to the human organism, especially in the respiratory tract. Causes cough, bronchitis and fatigue, and higher concentrations have toxic effects. Also, it causes harmful effects on wildlife. In winter, the heating facilities, SO_2 exists in the air of towns and settlements in higher concentrations.

In Zenica, the air quality has deteriorated due to increased emissions of SO_2 and other pollutants from thermal and metallurgical plants. Sulfur dioxide is predominantly transmitted from the industrial power plants in which the burning coal and gas technology with higher sulfur content, and natural gas in small quantities. As a result, residents of Zenica, the town of ferrous metallurgy in B&H, at risk of developing acute respiratory and other diseases that are correlated to air pollution increase [1, 2, 3]. Every winter, as a rule, in Zenica valley occurring episodes of high air pollution due to increased emissions of SO_2 and adverse weather conditions which are characterized by a stable atmosphere. Episodes of high air pollution produced by the formation of inversion layer due to the descent of cold air in the valley so that the layer of colder (more dense) air found under a layer of warm air. Below the inversion layer accumulate pollutants and worsening air quality. For these reasons it is necessary to ensure the control and evaluation of the level of air pollution with SO_2 or other pollutants that significantly pollute the air. A simple, rational and efficient control of air quality can be performed using appropriate models based on numerical methods.

PREDICTION OF AIR QUALITY

In order to control the emission level of air pollution SO_2 and other pollutants over certain areas, it is necessary to use effective methods for measuring and evaluating the impact of air pollution. Assessment and prediction of air quality using measured data base on the state of air quality and current meteorological conditions. The obtained results of evaluation air pollution are used as an effective tool for the selection and implementation of measures required to reduce emissions and air pollution in a defined area such as the Zenica basin. There are different methods of assessment and prediction of air pollution, and determining the contribution of individual pollutants that contaminate the same volume of airspace. Some methods are easier than others, but provide less relevant results and vice versa. Better predictions are those that use multiple assessment methods that include more input parameters, using the advantages of one method where the disadvantages of the other, all in order to achieve accurate prediction of air quality [4].

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Modeling of air pollution is an important tool for assessing air pollution in industrial and urban areas located in the deep basins such as the Zenica basin. In the deep valley of Zenica, limited by high mountains, lies a steel mill production capacity of 2 million t/y of steel which abuts the urban area of the town of Zenica, in which live more than 90,000 people exposed to emissions of various pollutants. Also, modeling air pollution should be an integral part of any study on the impact on the environment of the planned industrial facilities or activities. Modeling air pollution can be effectively predict the impacts of specific emission sources at the state of air quality, as on human health and the environment in general, on the basis of which provide for adequate measures to reduce emissions and air quality management [4, 5].

When the source of contamination of some pollutants emitted into the atmosphere from this source to a concentration (mass per unit volume) on the atmospheric air cannot retain its initial concentration. Atmospheric processes acting on pollutant so that it dispersed downwind reaching dilution concentrations of the pollutant. In simple terms, air dispersion models are computer tools that use mathematical equations to describe the processes of dispersion [6].

Local dispersion and attenuation of atmospheric pollutant concentrations of pollutants, can be mathematically modeled, or measurement of actual concentrations. Monitoring and data collection in relation to the mathematical modeling is more reliable, but also has its limitations quality measurement requires a large number of installed measuring stations, which are very expensive to maintain and service, and therefore a larger number of researchers chose to focus on a different model for calculation of the concentration of harmful substances in atmospheric air [4, 7]. Likewise, in the realization of new projects, measurement cannot be done, but we need information about potential emissions in order to assess their significance and impact on ambient air quality, and prediction of measures to reduce emissions.

Basically, the commonly used Gauss plume model, which predicts a ground floor concentration of harmful substances as a function of distance from the emission source, its height, emission flow, wind speed and dispersion coefficients. In this model, the concentration on the surface z = 0. Today in the world, Gaussian dispersion model is applied to all legislation, driven models such as the famous ISC (Industrial Source Complex) and 3D Screen (Lakes Environmental Screen View), which are distributed by the EPA (U.S. Environmental Protection Agency) [4].

Using data from the local measuring stations for monitoring air quality in terms of SO_2 imission is possible to determine the level of air pollution, but not to determine the true source of pollution (industrial stack, and / or other source) that the incidents could reduce emissions by switching to better fuel or reduce the volume of work, or volume of production and take other measures to reduce emissions and air quality protection. The most commonly used model simulations of the dispersion of pollution, because of its robustness and simplicity, is the Gaussian model of dispersion of pollution in the air [4, 8], which was used in this study with the aim of modeling the dispersion of the pollutant SO_2 from the point source industrial plants, as the dominant pollutant in relation to metering station at the location in Tetovo. This paper presents the assessment of ground level concentrations of SO_2 using a standard mathematical model [4]. Processing and presentation of input data with the above mentioned point source of SO_2 is a very important segment due to the sensitivity of the output (imission measuring SO_2). For comparison of modeled and measured values it has been analyzed data from monitoring stations for monitoring air quality (SO_2, for example, subject) of the University in Zenica in Tetovo locality in direct near the company Arcelor Mittal Zenica.

POLLUTANT DISPERSION MODEL

Emergence of complex processes in nature, and consequently in the atmosphere it can be described by mathematical models. Gaussian model Industrial Source Complex - Short Term (ISCST3 onwards) was used to simulate the dispersion on the basis of the basic Gaussian distribution for point sources and to establish stationary, ground level concentrations for a certain period of time. The model takes into account the complex configuration of the terrain (defined rectangular receptor grid), and subtlety of description field directly affects the accuracy of the results. Gaussian model calculated concentration pollutants at each predefined location, and defined by meteorological data. This allows the monitoring of impact of each source of harmful substances to their concentration in all pre-defined nodes receptor (imission) network. The formation of plumes of smoke (pick-up, transport, diffusion and deposition) under the direct influence of the defined hour of meteorological data that may result of in the situ measurements or in the alternative estimated. The origin of the coordinate system for each source and for each hour of the calculation, is located on the surface as the sources of pollution, and the absolute position of the receptor network nodes are translated into the local coordinate system of pollution sources. For a given source, the concentration of SO_2 at a distance of 300 m downstream (WNW) (Figure 1.) is represented by the following equation (1) [3]:

$$\chi = \frac{Q\,K\,V\,D}{2\pi U_S \sigma_y \sigma_z} e^{-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2} \quad (1)$$

where is: D - member of the dissolution, K - constant conversion (m), Q - emission of pollutants SO_2 (g/m^3), Us - wind speed at the exit of the chimney (m/s), V - Vertical member, y - Horizontal distance downstream from the headquarters of smoke (m), z - horizontal lateral distance from the headquarters of smoke (m), λ - the concentration of pollutants SO_2 ($\mu g/m^3$), σ_y - standard deviation of the horizontal dispersion, σ_z - standard deviation of the vertical dispersion

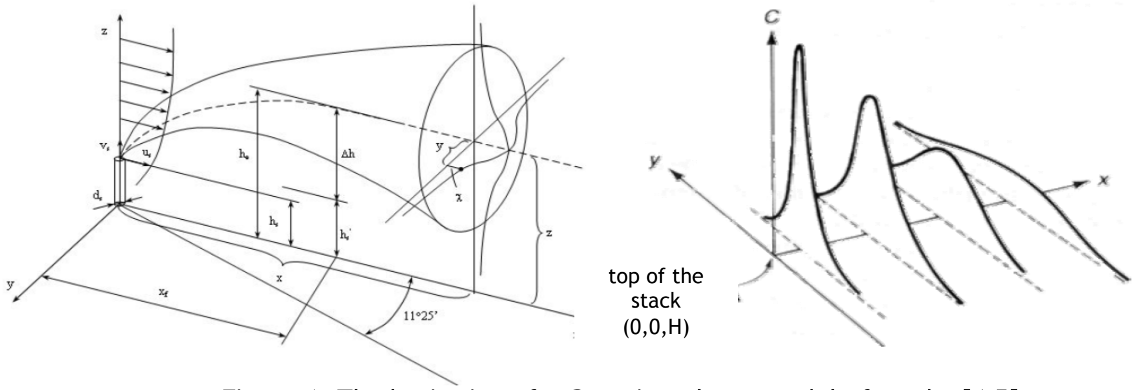

Figure 1. The basic size of a Gaussian plume model of smoke [4,5].

VALLEY OF ZENICA AS THE DOMAIN OF SO_2 DISPERSION MODELING

Using a dispersion model for continuous assessment of ground level concentrations of polluting substances from individual sources requires the selection of domain modeling. Specifically, it is necessary to determine the size and density of the receptor domain of points that will be estimated surface concentrations of pollutants such as SO_2, which are reviewed in this paper. The optimum size of the domain will be chosen so that the use of measured emissions of pollutants, such as in this example (case) is an industrial stack power plants located within the company, Arcelor Mittal Zenica, and meteorological data from weather stations in Zenica (wind rose, Image 2.). Subsequently it will be carried out simulations for a number of previous years and identify areas in which the surface concentrations above the annual limit value for the protection of human health and the environment in general [4, 9]. The domain is also necessary to include the location of measuring stations for air quality for validation and verification models, and to determine the share of individual sources of pollution in the overall measured level of air pollution. After that it is defined receptor network of the selected areas. Horizontal network, as the distance receptors or receptor network of horizontal resolution affects the accuracy of estimates of concentrations of SO_2. It is therefore necessary to create and use digital topographic maps of horizontal resolution of 100-300 m. Figure 2. presents satellite image of Zenica basin (which can be used for dispersion times (or flow) of SO_2 in the atmosphere), the position of stack power plants and the distance measuring stations for monitoring air quality in Tetovo [1].

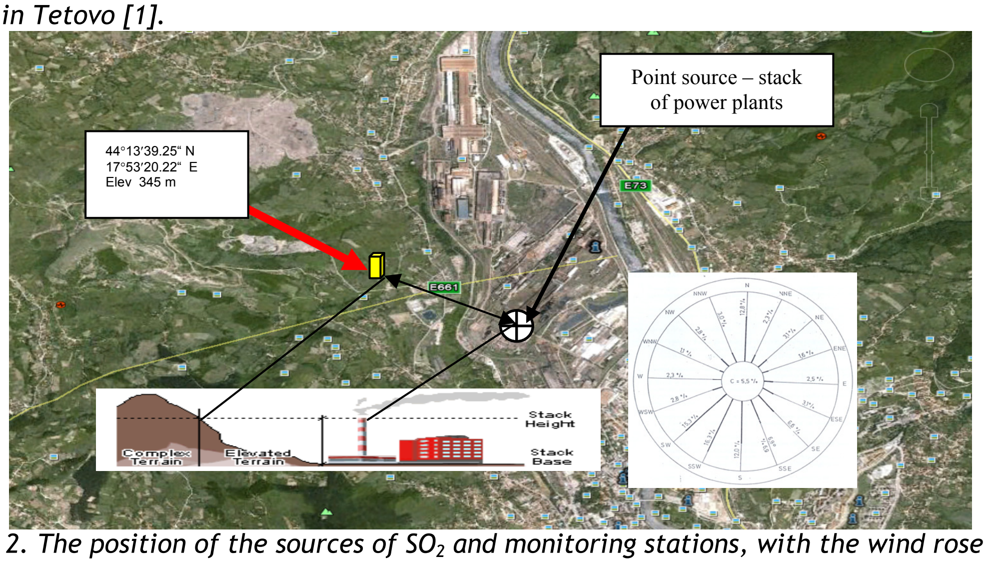

Figure 2. The position of the sources of SO_2 and monitoring stations, with the wind rose graph

The area of Zenica basin, where there are facilities of Arcelor Mittal Zenica (Figure 3.), belongs to the moderate climate of the continental Sub-Pannonia type. This area is characterized by the formation of temperature inversion, which prevents convective uplift of air. In winter and early spring months, the lower parts of depressions are sometimes fill colder air so that the layer of colder (more dense) air found under a layer of warm air. Therefore, in winter, caused by the emissions of harmful substances, leads to the formation of smog and increasing concentrations of SO_2, dust, soot (which favors prompt SO_2) and other pollutants in the lower layer of the atmosphere [4, 10, 11].

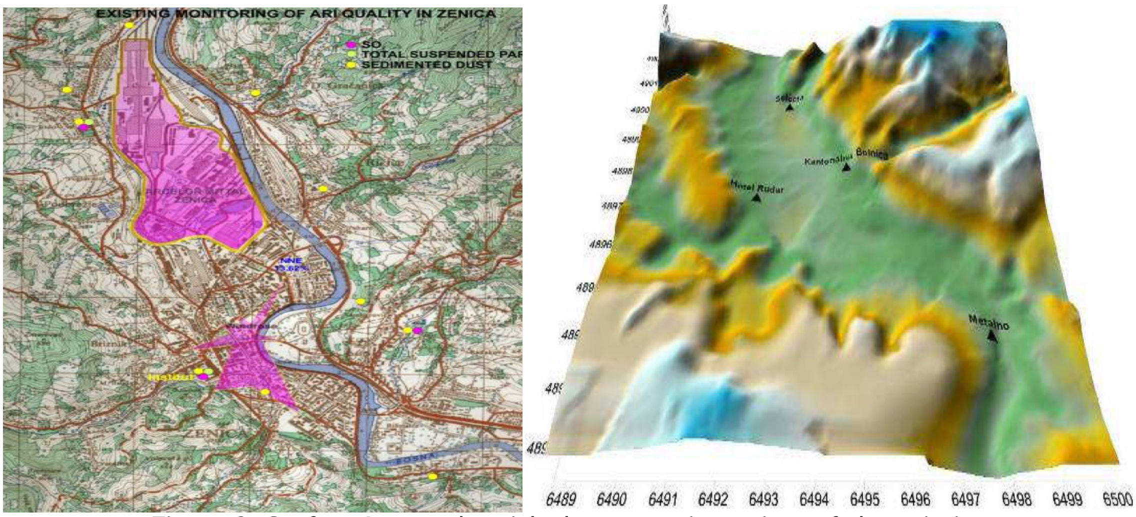

Figure 3. Surface Ironworks with the measuring points of the existing air quality monitoring and orographic 3D Zenica basin [10].

As a result of this space is turned away hills and forests, cold influences from the north have been reduced, so that the rare extreme cold, while summers are quite warm and with a certain daily and seasonal fluctuations. According to the Federal Meteorological Institute received decades-long monitoring of climatic elements on the meteorological station in Zenica, the average annual temperature in the Zenica area is 10.1 °C. The warmest month is July with an average temperature of 19.7 °C and the coldest is January with an average temperature of -0.9 °C. Temperature extremes indicate the occurrence of significant temperature fluctuations in relation to the average value and varies in the range of 40 to -23.9 °C [12]. Mean relative humidity based on several years of measurement is: 83% in winter and 72% in summer. An absolute maximum humidity is 90% and 54% absolute minimum. Humidity contributes to the formation of smog in winter [1, 12]

SYSTEM FOR PROCESSING INPUT DATA

For example, modeling the dispersion of SO_2 in Zenica valley has been used the average annual emission data and meteorological parameters. Continuous assessment of ground level concentrations of SO_2 can be made using multiple sources of input data and producing automated computational methods for interpolation of data on the domain model (Figure 2). In this way, the collected data are stored in the emission and meteorological database for historical analysis and year-round or for the simultaneous assessment of ground-level air pollution SO_2 [4].

Table 1. Technical description of the sources of pollution and meteorological parameters.

Name size	Unit	Value
Weather	2010.	-
Data on sources and emissions pollution		
The height of the stack	m	120
Diemeter of stack	m	5
Exhaust gas temperature	K	373,15
The emission of pollutants	gSO_2s^{-1}	582,75
The flow of flue gases	m^3/s	222,22
The average measured mass concentration of emissions in 2007.	mg/m^3	2625
Speed exhaust	m/s	11,32
Meteorological data		
Wind speed	m/s	1,1
Wind direction	^{o}	340
Solar radiation	W/m^2	95
Vertical temperature gradient	K/m	-1
Mixing height	m	1100

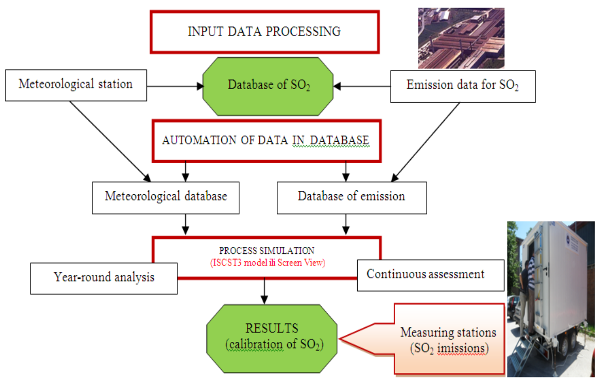

Figure 4. System for the preparation, calculation and visualization of ground level concentrations of SO_2 from industrial point sources.

Input data for the concerned Screen View model involving receptor network, data on emission sources and meteorological parameters (Figure 4.). Meteorological data required by the Screen View model include wind speed and direction, air temperature, high of mixing and atmospheric stability class, which is determined by the method based on the vertical gradient of temperature and solar radiation [4].

RESULTS MODELING AND ANALYSIS

Simulated the dispersion of SO_2 (take that for this local study of reactive SO_2) from industrial sources of heating for a certain period of time (2007.) based on realistic parameters listed in Table 1. For the selected time period of one year, the average daily concentrations of SO_2 at the *measuring point in the Tetovo was 112 µg/m3. Modeled value sensed from the diagram in Figure 5, the distance of 300 m of the analyzed emission sources, is 90 µg/m3 [13]*

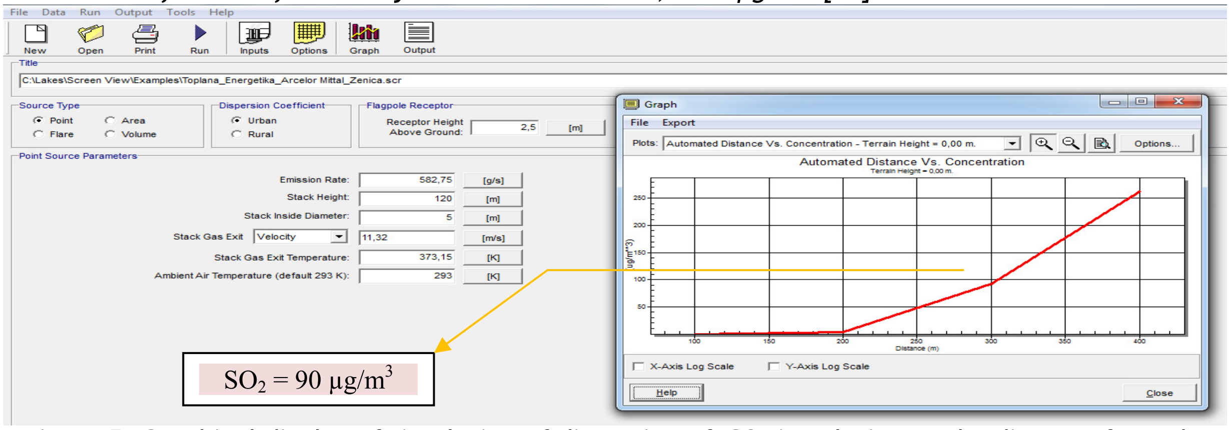

Figure 5. Graphical display of simulation of dispersion of SO_2 in relation to the distance from the source [4,12]

Comparison with Screen View model estimated ground level concentrations (Figure 2. and 3, and Table 2.) and measured values indicates the average 80.35% equity contribution to the total pollution (load) the air of sulfur dioxide Tetovo area.

Table 2. Modeled and the actual value of SO_2 imission

Model value λ_{SO2} ($\mu g/m^3$) Screen View	Reduced dispersion value of the wind direction (WNW, %) ($\mu g/m^3$)	The measured value of SO_2 measuring stations at the Tetovo ($\mu g/m^3$)	A emission part of heating plants in all immission (%)	Correction factor
90	0,99	112	80,35	1,24

During 2010. measurements were conducted continuous measurements of concentrations of SO_2 monitoring stations at Tetovo on the basis of which is getting constant previously determined relationship model and the actual value of imission (correction factor, Table 2) the simulation value of SO_2 (λ_{SO2}) for the period since 2006-2010. year. The results obtained are shown in Table 3. and Figure 6.

Table 3. Overview of model and actual values of imission SO_2 per year.

Year	2006.	2007.	2008.	2009.	2010.
Measured annual average concentrations of SO_2 ($\mu g/m^3$)	86	112	115	132	117,4
Model dispersion value of SO_2 ($\mu g/m^3$)	80,64	90	92,74	106,45	94,67

CONCLUSIONS

High concentrations of air pollution, a strong influence on human health, air quality and overall environment. Given the increasing economic and population growth is evident that the annual increase in air pollution and is therefore justified to research in the field of air quality modeling. In addition, the modern practice of favoring the use of the reference three-dimensional mathematical model to evaluate the level of air pollution, as well as an integral part of studies on the environmental impacts of planned new industrial complexes, manufacturing facilities and plants.

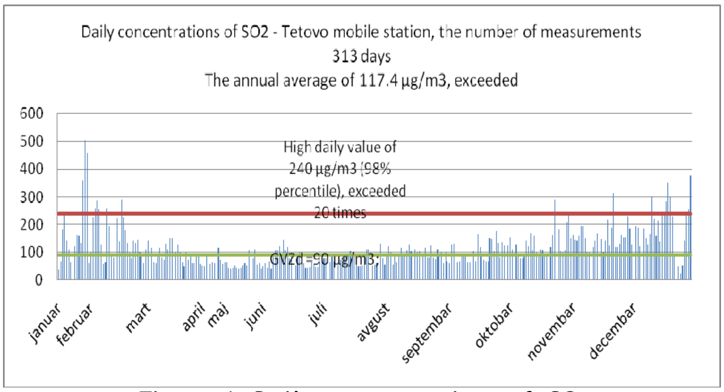

Figure 6. Daily concentrations of SO_2 at the location of Tetovo [1].

In this paper is presented and applied to a complex computer model of dispersion of SO_2 emitted from point industrial sources. The system of assessing ground level concentrations of air pollution which has been implemented within the computer model Screen View allows timely detection threshold limits, share some resources in excess of limit imission values, and determining the threshold limits in an area where there are no monitoring stations for monitoring air quality. In this way it is possible to respond timely to implement emergency measures aimed at reducing emissions, such as for example a temporary substitution of fuel or raw materials are environmentally suited to the type of or decrease in production capacity to meet the legally prescribed limit emissions and therefore contribute to the protection of human health and in all its aspects.

Lower and upper assessment threshold allows the use of computer models to determine the need for the installation of additional measuring stations in places exceeding imission values. Presented a system of assessment can be easily adapted for a several days prediction ground level *concentrations of pollutants in the air on the basis of projected emissions and predicted meteorological fields using regional meteorological models.*

Regarding the specific case of modeling the dispersion of SO_2 from the point source of industrial power plants in Zenica valley noted a need for testing and modeling the dispersion of this or any other pollutant in ground layers of the atmosphere in the other direction with dominant winds, and the second measuring imission counts. Also of great importance would be to examine the impact of SO_2 in air quality from other dominant point sources and smaller surface of widespread sources that significantly affect the contamination of surface layers of the atmosphere, especially in winter, with stable atmospheric conditions. Dispersion can be further complicated by taking into account the overlay of pollutants and their interactions, which simplifies the modeling and neglect.

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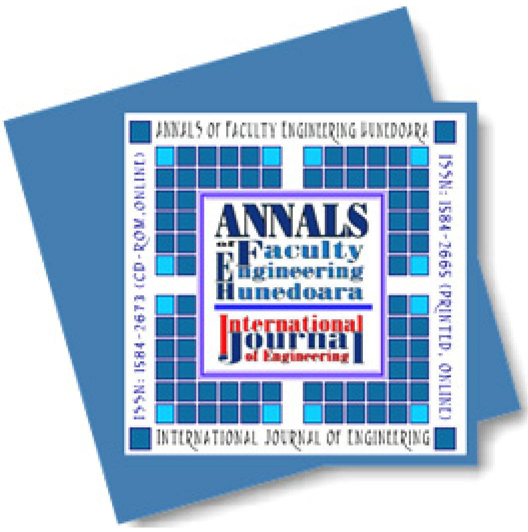

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