AIR QUALITY MONITORING AND MODELING NEAR COAL FIRED POWER PLANT

by

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In municipality of Ugljevik (Bosnia and Herzegovina), the coal-fired thermal power plant is located in the vicinity of the populated area. The ambient air quality monitoring within this area were not systematically performed in the previous period. This research was the first to include indicative measurement of pollutant concentration in air combined with modeling techniques for the purpose of a preliminary assessment of impact which the power plant has on air quality. Since coal, with the sulfur content of 3-6%, is used, as well as the fact that there was no flue gas desulphurization during the research period, this paper shows the results for SO_2 as one of the most prominent indicators of pollution originating from the power plant. As a complement to the measurements, modeling of SO_2 dispersion was carried out using ADMS5 software. The measurements indicated increased ground-level concentrations of SO_2. Additionally, the modeling of SO_2 dispersion with real meteorological data was carried out. The modeling confirmed high SO_2 concentrations in research area. Also, it was found that the high episodic ground-level SO_2 concentrations are the consequence of the terrain configuration and meteorological conditions.

Key words: *SO_2, air pollutant dispersion, ADMS5, air quality assessment, large combustion plants*

Introduction

The growing environmental problem, which follows the industrialization, urbanization and intensification of road transport, is air pollution [1, 2]. From the aspect of heat and electricity production in power plants, combustion of fossil fuels, primarily coal, poses a serious threat to human health and global environment [3-6]. Besides emission of GHG, the energy sector releases a huge amount of heavy metals, particulate matter, NO_x, and SO_2. Emissions from energy sector is responsible for 69% of global SO_2 emissions [7]. Various studies have shown that health risk exists for short term exposure to high SO_2 concentrations. However, SO_2 has been identified as non-cancerous pollutant [8, 9].

Although significant shift from fossil fuel to green energy production occurred in last decade, coal remains the most used fuel in energy production sector, chemical industry

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and metallurgy sector. The coal-fired thermal power plants (TPP) are still main contributors to atmospheric releases of CO_2, NO_x, and SO_2 [10].

Twenty-nine coal fired TPP are located in the territory of Western Balkans, and nine at the territory of Bosnia and Herzegovina. In the area of Ugljevik municipality there is a TPP complex with one boiler of 350 MW capacity. The treatment of flue gases is carried out by two electrostatic precipitation, which are in poor condition despite the frequent maintenance. The TPP in Ugljevik had no NO_x and SO_2 emission control. The construction of a FDG plant has begun in 2017 [11,12]. Due to the high content of sulfur in fuel (3-6%) [13] and lack of flue-gas desulfurization, this facility generates 154 kt per year of SO_2 [14].

Today, all EU member states, candidate states and potential candidate states like Bosnia and Herzegovina must implement and enforce measures to comply with EU Air Quality Framework Directive [15]. As a first step in enforcement of the national legislation, municipality of Ugljevik provided preliminary ambient air quality assessment. So, at the area around TPP, three monitoring campaigns were conducted. The concentration of SO_2, NO_x, suspended particles (PM2.5 and PM10), CO, O_3 as well as meteorological parameters were measured. Furthermore, the study was focused solely on SO_2, due to coal high sulfur content and absence of FGD.

Since the monitoring data were not enough to access the air quality, the modeling techniques were used. Modeling and simulation of SO_2 dispersion from TPP through various models has been the subject of numerous researches in the field of environmental protection [16, 17]. For modeling and simulation of air pollution dispersion as well as for the prediction of impact on the environment and human health, it is best to use Gaussian dispersion models because of their simplicity and fast response time. One of the Gaussian dispersion models that became widely used in Europe, the atmospheric dispersion modeling system (ADMS5) [18] was used for SO_2 dispersion simulation.

Materials and methods

As the systematic analysis of air quality coupled with modeling had not been carried out by the time this research begun, the aim was to determine the level of air pollution as well as to identify the exposed zones near TPP in Ugljevik city. Hence, the research was carried out in two phases. The first phase included three measurement campaigns while the second one included the simulation of SO_2 dispersion in real environment.

In situ air quality measurements

During three seasons (spring, fall and winter), indicative measurements of ambient air quality were carried out at four measuring points [15]. The position of pollution source, and monitoring sites are shown in fig. 1. Measuring sites were selected as locations which are the potentially mostly influenced by the emission source according to the prevailing meteorological condition in the region, as well as according to terrain configuration. Monitoring was conducted during the 30 days in each of the campaigns. At automatic station located at city center (M4), the hourly values of SO_2 and meteorological parameters during each campaign was conducted. At the remaining three sites (M1, M2, and M3) the measurement of daily SO_2 concentration values was being carried out successively for seven days during the campaigns.

Air Pointer Instrument (RECORDUM) was used to measure hourly meteorological parameters and SO_2 concentrations. Station was located in the city center, at 2.5 km distance from the pollution source in the north-east direction according to the source. The Air Pointer

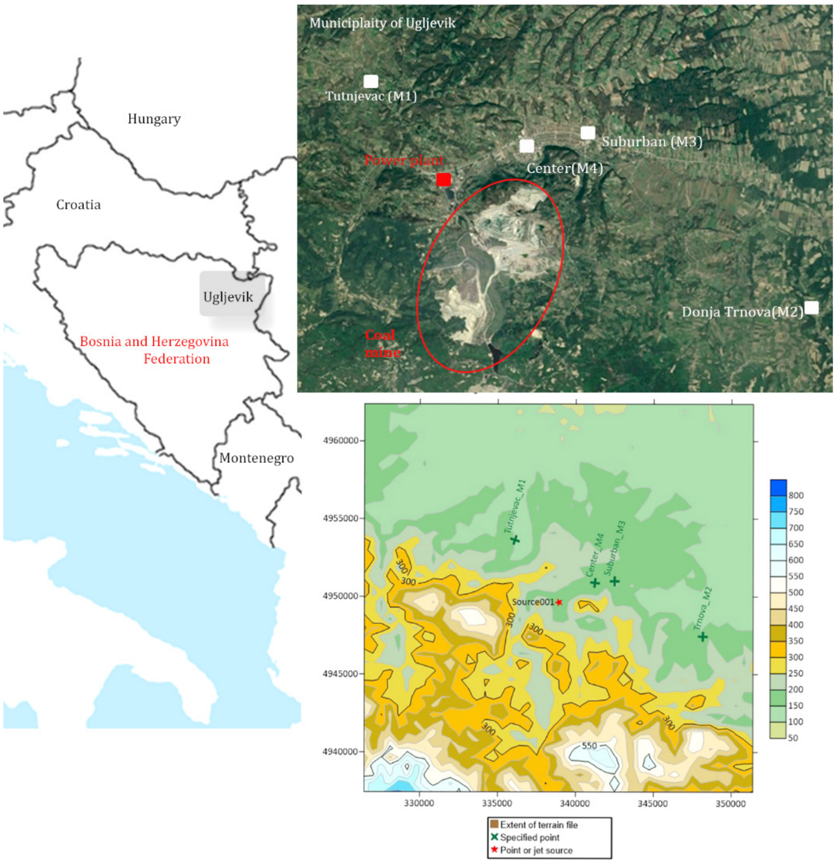


Figure 1. Analyzed site domain, position of measurement sites and complex terrain visualization in WGS_1984_UTM_Zone_34N

Instrument has a modular desing and is fitted with: NO/NO_2 chemiluminescence principle (EN14211) module; SO_2 an UV fluorescence (EN14212) module; O_3 an UV absorption (EN 14625); CO an Non-dispersive Infrared (NDIR) Gas Filter Correlation (EN14626) module; Volatile Organic Compounds (VOC) as Photo Ionization Detector (PID) module; PM10 based on nephelometry principle.

The AT-401X device was used for passive sampling of SO_2 at M1, M2, and M3. The device has an option to electrically control different parameters including pressure and air temperature measurement, pressure in the inlet system, regulation and measurement of mass-flow.

The ambient air samplers have been set up in accordance with the requirements defined in the Regulation on monitoring conditions and air quality requirements that include: free air-flow (at least 270°) without obstructions that could affect the flow, at 1.5 m (respiratory intake level), distance from the pollution source *etc*. The reference method for SO_2 described in the standard SRPS EN 14212, ambient air quality: Standard method for SO_2 concentration measuring based on ultraviolet fluorescence was used.

Dispersion model

To model the atmospheric dispersion of SO_2 emitted by TPP, the Gaussian dispersion model ADMS5 was used. The ADMS5 was designed by Cambridge environmental research consultants (CERC) specifically for assessing air quality impacts of industrial sites. ADMS5 has the possibility to create hourly and daily short-term (ST) as well as long-term (LT) concentration propagation scenarios. The ADMS5 allows flexible input meteorological data but minimum parameters required to run (besides timing) are: wind speed and direction, temperature, humidity, pressure and at least one of: reciprocal of the Monin-Obukhov length; the surface heat flux; or the cloud cover. The model options are various inputs and output capabilities, like dry and wet deposition, puffs, NO_x chemistry, time varying sources, variable roughness, *i. a.* Based on recent research, one should have in mind that all available atmospheric pollutant dispersion models are more or less accurate, over or under-estimating predictions [19, 20].

Input data

Study area (terrain and meteorological data) – The city of Ugljevik is in the eastern part of Bosnia and Herzegovina. The TPP complex is in the vicinity of a populated place while the closest residential buildings are situated at only 200 m. This research included simulation of a real modeling environment where complex terrain module was performed. A domain of 25×25 km (center is the TPP) is defined, with a resolution of 50 m. Field simulation data are defined in the corresponding file with coordinates in WGS_1984_UTM_Zone_34N with EPSG code 32634, fig. 1. The meteorological data (wind speed – WS, wind direction – WD, atmospheric pressure – P, relative humidity – RH, and dew point-Dew) measured at M4 were used for SO_2 dispersion modeling.

Emission sources – The boiler was constructed in 1983. Brown coal is used as the main energy source which is exploited at the vicinity of the TPP itself. The average annual electricity production of this TPP is 1560 GWh. Flue gases are released into the atmosphere from 300 m high stack.

The ADMS5 uses data on pollutant emission rate, stack characteristics (position, height and diameter) as well as the flue gas parameters (temperature, exit flux: volume or velocity).

Depending on emission source type, as an input, ADMS5 uses different types of emission rates. According to the available emission parameters, emission rate for point sources [gs^{-1}] could be calculated by simple equation: $E_i = C_i \times Q_{fg}$, where E_i [gs^{-1}] is calculated emission rate of specific pollutant, C_i [mgm^{-3}] – the concentration of measured pollutant at stuck, and Q_{fg} [m^3h^{-1}] – the a flow rate of flue gas.

Since a range of SO_2 concentration and flue gas flow rate has been reported [13], for the purpose of this research, the most undesirable scenario, upper emission concentration (24394 mg/m^3) and flow rate of SO_2 (1815100 m^3/h) were used.

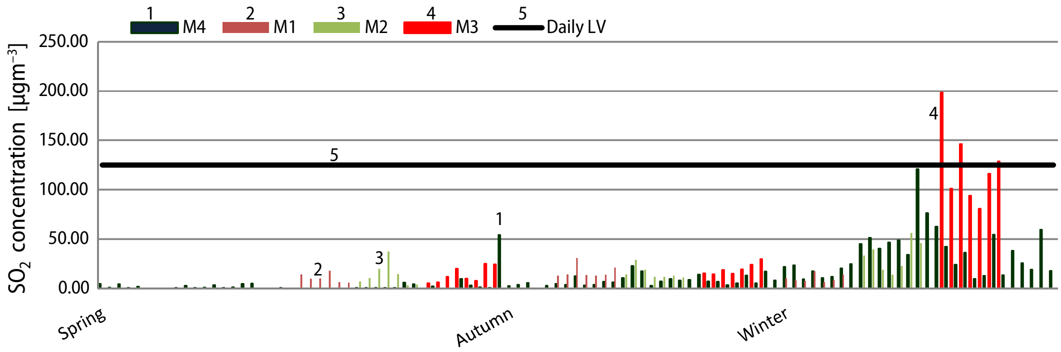
The results obtained from the air dispersion model could be more accurate if time-varying emissions in form of input file are used instead of single, constant value for emission output rate [21]. However, in many cases access to continuous emission monitoring data is not possible either due to lack of installed monitoring equipment or difficulties in obtaining those data from TPP operator. In our case a single averaged SO_2 emission concentration value was used, as constant release at one stack. One known uncertainty in projected simulated results was introduced due to lack of information available for SO_2 background concentrations and residential heating emissions. However, as residential heating that are not connected to centralized heating system is mostly assured by wood stoves and natural gas boilers, that does not contain sulphur, authors considered safe to assume that those sources are not contributing significantly to SO_2 background concentrations.

Results and discussion

In situ sulfur dioxide air quality monitoring results

In order to quantify the SO_2 emission from TPP Ugljevik and its impact on air quality in the surrounding area, several relevant criteria for optimal distribution of analyzers should be adopted, those are spatial representativeness and the ability to detect violations of imposed air quality standards. This criterion can be integrated in well-known multi-objective optimization algorithms like Non-dominated sorting genetic algorithm (NSGA-II) to provide Pareto optimal solutions for an optimum choice of areas where SO_2 analyzers should be installed [22]. However, this extended analysis for optimal instrument set-up is not always possible, as in this study, when the instruments were deployed for short to midterm period, and when the security and electricity availability for instruments were the most relevant criteria.

The SO_2 concentrations for all monitoring sites during three campaigns are given on fig. 2.



Fugure 2. Daily SO_2 concentration during three campaings
(*for color image see journal web site*)

During the spring campaign, data coverage of SO_2 concentration at M4 was less than 90%, so it was not considered in this paper. However, during the spring and fall campaign, at M1, M2, and M3, SO_2 concentration levels were below the daily limit values (DLV) of 125 μg/m^3. At the M4, the DLV, hourly limit value (HLV) of 350 μg/m^3 as well as threshold limit value (TLV) of 500 μg/m^3, were not exceeded in fall campaign. For the winter campaign it could be noted that concentrations at all measurement sites were increased compared to the spring and fall campaign. At M3, during the winter campaign, exceedance of DLV for 3 days (43%) was recorded. The maximum daily concentration at M3, was 198.51 μg/m^3. On the other hand, at M4 site, during the same campaign, an exceedance of HLV and DLV was not recorded, but the overall concentrations were increased compared to the fall campaign, figs. 2 and 3.

Since daily average concentration values were measured at three points, critical periods of the day when higher concentrations were noted cannot be indicated. However, hourly SO_2 concentrations from the site M4, indicated the increase during the nights and early mornings which could relate to the morning inversions [23]. The complexity of interaction between the weather conditions and distribution of pollutants, as well as the increase in concentration near large sources has been investigated in recent studies [24, 25]. During the measurement campaigns, the data indicated that meteorological conditions had changed just before the increase in concentration levels in winter campaign. Before the concentration increase, WSW, SW, SSW, and NNE winds of the speed class from 0.5 to 2.1 m/s were dominant. However, the

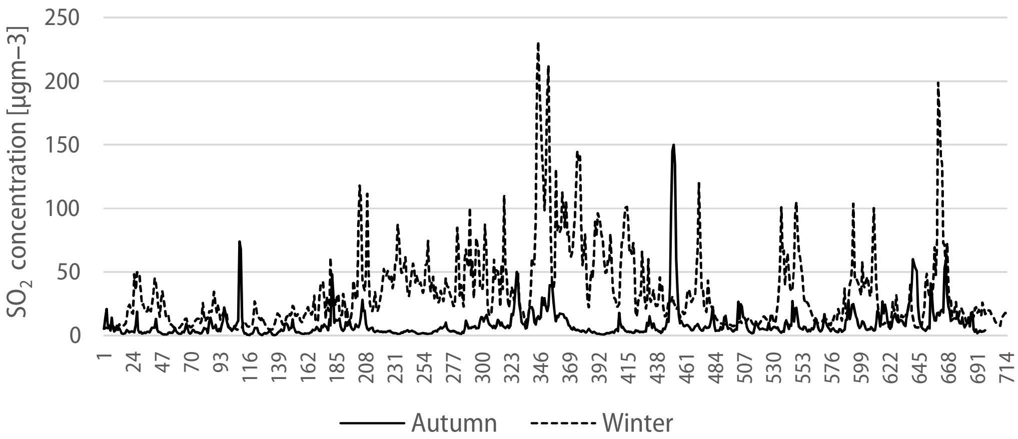


Figure 3. Hourly SO_2 concentrations at M4 during the fall and winter campaign

period of increased SO_2 concentration was characterized by a higher proportion of calms (over 45%), decrease in atmospheric pressure (below 1000mbar), temperature rise (more than 5 ºC) followed by higher dew points and relative humidity. Finally, the high concentration of SO_2 confirmed that air pollution is evident in this area. Air quality can be classified in the second category, since the limit values were exceeded, but the exceedance of TLV was not recorded.

Sulfur dioxide dispersion modeling results

Since there are no hourly concentration data at the majority of the monitoring sites, the origin of pollution and SO_2 concentration increase could be potentially indicated by pollution dispersion modeling.

After preprocessing the input data, two sets of modeling were performed: Long term modeling at specified receptor points (measurement sites) in order to make a comparison between measured and modeled data, which is also a confirmation that adequate simulation model was established; long term modeling for whole domain in three campaigns in order to assess preliminary ground concentration levels, SO_2 distribution patterns as well as the identification of the most endangered zones.

Results of modeling at specified receptor points (measurement sites)

Assuming that there were no significant fluctuations in SO_2 emission rate, a single averaged SO_2 emission concentration value was used, as constant release on TPP stack. In order to set up the domain and dispersion model, long term simulation for specified receptors (measurement sites) were performed.

The study area is relatively small (625 km^2) with a large number of defined receptor points, and literature showed that the sensitivity and uncertainty of atmospheric dispersion models such as ADMS, AERMOD, a.o. are very good on 1 hour and 24 hours' time averaging scales [26].

The modeling concentration data are presenteted according to the average concentration measured at the monitoring sites: for M1, M2, and M3 daily (24 hours) concentration, and for M4 hourly (1 hour) averaged concentration, tab. 1.

The modeled concentrations for the spring campaign were very high at specific points in relation to the measured concentrations. This relatively weak correlation between measured

Table 1. Average measured and modeled - long term (LT) for 1 hour and 24 hours – concentration at specified points (measurement sites) for all three campaigns

Campaign	Spring		Fall		Winter	
Conc. [μgm^{-3}]	Measured	Modeled	Measured	Modeled	Measured	Modeled
M1 LT [24 hours]	10	66	17	14	10	9
M2 LT [24 hours]	13	157	15	14	32	30
M3 LT [24 hours]	13	82	19	13	189	213
M4 LT [1 hour]	–	65	1.36	2	34	23

and modeled concentrations indicates the possible changes in emission rate due to overhaul, unexpected malfunctions or reduced production capacity [27]. Different than in spring, in the fall and winter season modeled data significantly correlate with the measured values. As in the case of the measured concentrations, higher concentration levels are also noted in modeled concentrations for the winter season, tab. 1.

The variation degree of modeling and measuring data is determined by the quality of the model input data and monitoring sites reprezentativnes as well [28]. Many case studies use Gaussian models to report variations in measured and modeled ground concentration levels of SO_2 per hour and 24 hours due to emissions from thermal power plants [17]. Besides, the EU Directive (2008) [15] defines the goals for achieving data quality objectives for ambient air quality assessment obtained by different techniques where modeling uncertainty of 50% for hourly and daily concentrations and 30% for annual values were defined. Pre-estimated or under-estimated modeled concentration in this study is the consequence of three data inputs: Unavailable data on emission from residential heating as well as time varying emission rate form the TPP stack. These data are the crucial input parameters for model accuracy [29, 30]; unvailable data on background SO_2 concentrations; drawback of the ADMS5 which by default does not model calm conditions (wind speeds measured at 10 m height are less than 0.75 m/s) especially when the complex terrain module is used [31]. This was an additional limiting factor during the dispersion simulation over the period of higher concentrations when the effect of calms was significant [32].

Regardless of these factors, simulations for the fall and winter campaign indicate the sensitivity to real meteorological conditions and consequently, the modeled concentration correlate with the measured sulfur dioxide concentrations in the range defined by EU Directive [15]. Hence, modeling with the available input data can serve as an indication of the ground SO_2 concentration levels and of the concentration fluctuations due to weather conditions.

Long term modeling for whole domain in three campaigns

As modeled concentrations at specific points during the fall and winter campaign correlate with the measured concentration values, in order to identify the most vulnerable areas, the modeling for the field of area in radius of 25 km around the TPP Ugljevik was carried out. Results of LT modeling for whole domain in three campaigns are presented in tab. 2.

Generally, for the all measurement campaigns, high SO_2 concentrations were modeled which is indicated by the maximum hourly concentration and 98th percentile of hourly concentration (C98th), tab. 2. High modeled concentration during the spring and winter campaign are the consequence of the low wind speeds and great share of calms during the measurement campaigns. In general, modeled concentrations overestimate measured concentrations in most of the LT simulations period which could be the consequence of the meteorological data accuracy

Table 2. Ground level (LT) modeled SO_2 concentration

Modeled concentration LT (1 hour) [μgm^{-3}]	Maximum [μgm^{-3}]	Average modeled concentration [μgm^{-3}]	C98th [μgm^{-3}]
Spring	519	94	391
Fall	165	22	120
Winter	211	44	165

[33]. Modeled SO_2 2-D and 3-D concentration contour maps for all campaigns are presented on fig. 4.

Identified vulnerable areas in all three campaigns are mainly in the domain of the surface coal mine which is not highly populated. By analyzing the numerical model outputs, it is identified that the highest ground SO_2 concentration is are modeled on relatively high altitudes (over 300 m a.s.l).

Since the measuring points were set relatively close to the point source, with relatively low probability of pollution detection due to the source height [13, 34], as well as there are no data on other small SO_2 sources (residential heating, individual small combustion units *etc.*), it cannot be reliably specified what are the causes of such concentration increase. However, combination of measuring and modeling techniques in this study pointed out that pollution episodes which ocurre in this area are the consequence of the terrain configuration [35] and the way how the typical climate conditions affect this area.

One can also note the importance of using the pollutant dispersion models for air quality assessment of existing or planned industrial installations, to design the regional or urban air quality monitoring networks.

This ADMS study shows that the highest obtained values after SO_2 dispersion simulation are noted on the south of Ugljevik TPP stack, where installation of monitoring equipment could provide better results in terms of standards compliance validations.

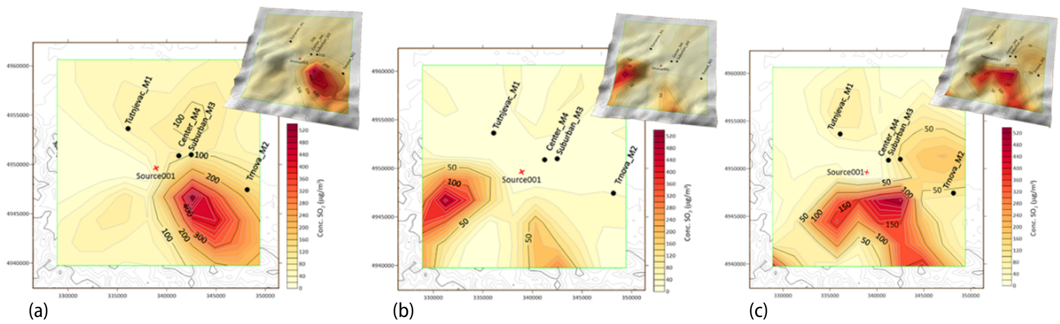


Figure 4. The 2-D and 3-D contour maps of modeled SO_2 concentration [μgm^{-3}] (WGS84) during the spring (a), fall (b) and winter (c) campaign (*for color image see journal web site*)

Conclusion

This study shows the results of measurement and modeling of SO_2 concentrations during the three campaigns (spring, fall, winter) in residential area near coal-fired power plant.

The measurements indicated that during the winter campaign, higher SO_2 concentration were noted at three measuring sites (M2, M3, M4) compared to the concentrations obtained during spring and fall campaign. Also, during the winter measurement campaign there was an episodic increase in the concentration of SO_2 at two measuring sites (M3 and M4).

Gaussian dispersion model ADMS5 was used as an additional tool for point source impact assessment of research area and to evaluate the simulation overlap over ground SO_2 monitoring stations. In that sense, two sets of simulations were conducted. The first simulation set involved modeling of concentration levels at specific points (measurement sites) in order to make a comparison between measured and modeled data and to set up the model input data. Another simulation set was conducted with the goal to obtain concentration levels for the whole research domain and identification of the most endangered zones. The both simulation sets were provided with the assumptions that there are no time varying emission rates at the TPP stack with no data on SO_2 background concentration and influence of other potential SO_2 sources. However, the modeling results showed that the structure of the surrounding area and the altitude of the pollutant source itself are the parameters which contribute to the fact that extremely high concentrations are modeled at locations of high altitudes

It is evident that in this area the air pollution represents a major problem. Although the legislation in Bosnia and Herzegovina is harmonized with the high standards of the European Union regarding acceptable concentration levels, it is impossible to take technical measures within the defined deadlines especially if we consider that the equipment is outdated and that there are financial restrictions for new investments.

To increase the accuracy of projected SO_2 trajectories obtained from ADMS5 (or other models) multiple tools and spatial measured data could be integrated in analysis, such as Aerosol Optical Depth and Ångström Exponent, values that can be measured locally, obtained from AERONET (AErosol RObotic NETwork) or derived from MODIS (Moderate Resolution Imaging Spectroradiometer) space observations [36]. In this particular case, for Uglevik TPP, it would be difficult to improve the accuracy of the model results, as the closest AERONAT stations are in Timisoara (RO), Tremiti (IT), and Kanzelhohe (AT) so ADMS5 model algorithm based on Gaussian plume air dispersion based on boundary layer depth and Monin-Obukhov length parameters was used with default options.

Since extensive research has not been carried out yet within this area, combination of modeling and measurement, can serve as a basis for ambient air quality improvement plans, pollution control strategies, establishing representative monitoring network and a framework of health impact assessment in accordance with the recommendations given by the EU and WHO. Further research should be focused on the more extensive monitoring in terms of the number of sampling points and time coverage, but the main effort should certainly be focused on the power plant flue gases cleaning equipment modernization.

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References

[1] Goudarzi, G., *et al*., Health Risk Assessment of Exposure to the Middle Eastern Dust Storms in the Iranian Megacity of Kermanshah, *Public Health., 148* (2017), July, pp. 109-116
[2] Khaniabadi, Y. O., *et al*., Modelling of Particulate Matter Dispersion from a Cement Plant: Upwind-Downwind Case Study, *Journal of Environmental Chemical Engineering, 6* (2018), 2, pp. 3104-3110
[3] Dios, M., *et al.,* Experimental Development of CO_2, SO_2 and NOx Emission Factors for Mixed Lignite and Subbituminous Coal-Fired Power Plant, *Energy, 53* (2013), May, pp. 40-51
[4] Darmastuti, Z., *et al.,* SiC–FET Based SO_2 Sensor for Power Plant Emission Applications, *Sensors and Actuators, B: Chemical, 194* (2014), Apr., pp. 511-520
[5] Wang, L., Predicted Impact of Thermal Power Generation Emission Control Measures in the Beijing-Tianjin-Hebei Region on Air Pollution over Beijing, China, *Scientific Reports, 8* (2018), 934

[6] Rathnayake, M., *et al*., Utilization of Coal Fly ASH and Bottom ASH as Solid Sorbents for Sulfur Dioxide Reduction from Coal Fired Power Plant: Life Cycle Assessment and Applications, *Journal of Cleaner Production, 202* (2018), Nov., pp. 934-945

[7] Ramadan, A. A., *et al.,* Total SO_2 Emissions from Power Stations and Evaluation of their Impact in Kuwait Using a Gaussian Plume Dispersion Model, *American Journal of Environmental Sciences, 4* (2008), 1, pp. 1-12

[8] Zhao, W. C., *et al*., Levels, Seasonal Variations, and Health Risks Assessment of Ambient Air Pollutants in the Residential Areas, *International Journal of Environmental Science and Technology, 10* (2013), 3, pp. 487-494

[9] Amster, E. D., *et al.,* Contribution of Nitrogen Oxide and Sulfur Dioxide Exposure from Power Plant Emissions on Respiratory Symptom and Disease Prevalence, *Environmental Pollution, 186* (2014), Mar., pp. 20-28

[10] ***, European Environment Agency, Air quality in Europe, Sulphur dioxide (SO_2) emissions, Indicator Assessment, 2015, ISSN 1977-8449. DOI:10.2800/62459

[11] Stojanović, B., Đukić, S., Prioritetne obaveze termoelektrana u narednih nekoliko godina sa posebnim osvrtom na termo elektranu Ugljevik (Priorities for LCPs in next few years, with the focus on LCP in Ugljevik – in Serbian), *Proceedings*, International Conference "Power Plants 2014", Zlatibor, Serbia, 2014

[12] Arsenović, B., *et al.,* Ispitivanje kvaliteta vazduha na području grada Bijeljina (Air Quality Assessmnet in Bijeljina – in Serbian), *Proceedeings*, International Scientific Conference, Bijeljina, 2015, pp. 126-130

[13] ***, Environmental impact assessment of surface coal mine „Ugljevik - East 1"Institute for construction Banja Luka, 2016. https://doi.org/10.1016/j.apr.2017.06.001.

[14] Holland, M., Technical Report – Health Impacts of Coal Fired Power Stations in the Western Balkans, 2016, https://env-health.org/IMG/pdf/technical_report_balkans_coal_en_lr.pdf

[15] ***, Directive 2008/50/EC of The European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Official Journal of the European Union. L 152, 1-44

[16] Yassin, M. F., Al-Awadhi, M. M., Impact of Sulphur Dioxide Emissions of Power Stations on Ambient Air Quality, *Environmental Engineering Science, 28* (2011), 7, pp. 469-475

[17] Gibson, M. D., *et al.,* Dispersion Model Evaluation of PM2.5, NO_X and SO_2 from Point and Major Line Sources in Nova Scotia, Canada using AERMOD Gaussian plume air dispersion model, *Atmospheric Pollution Research, 4*, (2013), 2, pp. 157-167

[18] Leelossy, A*., et al.,* Dispersion Modelling of Air Pollutants in the Atmosphere: A Review, *Central European Journal of Geosciences, 6* (2014), 3, pp. 257-278

[19] Kalhor, M., Bajoghli, M., Comparison of AERMOD, ADMS and ISC3 for Incomplete upper Air Meteorological Data (Case Study: Steel plant), *Atmospheric Pollution Research, 8* (2017), 6, pp. 1203-1208

[20] Righi, S., *et al*., Statistical and Diagnostic Evaluation of the ADMS-Urban Model Compared with an Urban Air Quality Monitoring Network, *Atmospheric Environment, 43* (2009), 25, pp. 3850-3857

[21] Douglas, P., *et al.,* Sensitivity of Predicted Bioaerosol Exposure from Open Windrow Composting Facilities to ADMS Dispersion Model Parameters, *Journal of Environmental Management, 184* (2016), Part 2, pp. 448-455

[22] Hao, Y., Xie, S., Optimal Redistribution of an Urban Air Quality Monitoring Network Using Atmospheric Dispersion Model and Genetic Algorithm, *Atmospheric Environment, 177* (2018) Mar., pp. 222-233

[23] Deligiorgi, D., *et al.,* Estimation of Pollution Dispersion Patterns of a Power Plant Plume in Complex Terrain, *Global NEST Journal*, *15* (2013), 2, pp. 227-240

[24] Matthaios, V. N., *et al.,* Interactions between Complicated Flow-Dispersion Patterns and Boundary Layer Evolution in a Mountainous Complex Terrain During Elevated SO_2 Concentrations, *Meteorol Atmos Phys., 129* (2017), 4, pp. 425-439

[25] Shu, L., *et al.,* Regional Severe Particle Pollution and its Association with Synoptic Weather Patterns in the Yangtze River Delta Region, China, *Atmospheric Chemistry and Physics, 17* (2017), 21, pp. 12871-12891

[26] Zou, B., *et al.,* Performance of AERMOD at Different Time Scales, *Simulation Modelling Practice and Theory, 18* (2010), 5, pp. 612-623

[27] ***, RITE Ugljevik, http://riteugljevik.com (accessed 13.12,2018.).

[28] De Hoogh, K., *et al.,* Comparing Land Use Regression and Dispersion Modelling to Assess Residential Exposure to Ambient Air Pollution for Epidemiological Studies, *Environment International, 73* (2014), Dec., pp. 382-392

[29] Mahboob, A., Makshoof, A., Dispersion Modeling of Noxious Pollutants from Thermal Power Plants, *Turkish J. Eng. Env. Sci., 34* (2010), 2, pp. 105-120

[30] Milosavljevic, B. Lj., *et al.,* Measurements and Modeling Pollution from Traffic, *Thermal Scince, 19* (2015), 6, pp. 2093-2104
[31] ***, CERC 2012-Cambridge Environmental Research Consultants-ADMS 5 User Guide
[32] Josipović, M., *et al.,* Comparisons of Meso-Scale Air Pollution Dispersion Modelling of SO_2, NO_2 and O_3 Using Regional-Scale Monitoring Results, *Clean AirJournal, 18* (2010), 1, pp. 3-8
[33] Mohtar, A. A. A., *et al.,* Variation of Major Air Pollutants in Different Seasonal Conditions in an Urban Environment in Malaysia, *Geoscience Letters Official Journal of the Asia Oceania Geosciences Society (AOGS), 5* (2010), Sept., 21
[34] Valverde, V., *et al.,* A Model-Based Analysis of SO_2 and NO_2 Dynamics from Coal-Fired Power Plants under Representative Synoptic Circulation Types over the Iberian Peninsula, *Science of the Total Environment, 541* (2016), Jan., pp. 701-713
[35] Ichikawa, Y., Sada, K., An Atmospheric Dispersion Model for the Environmental Impact Assessment of Thermal Power Plants in Japan – A Method for Evaluating Topographical Effects, *Journal of the Air & Waste Management Association, 52* (2002), 3, pp. 313-323
[36] Sagan, V., *et al.,* SO_2 Trajectories in a Complex Terrain Environment Using Calpuff Dispersion Model, OMI and MODIS Ddata, *International Journal of Applied Earth Observation and Geoinformation, 69* (2018), July, pp. 99-109

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