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IMPACT OF THERMAL POWER PLANTS “NIKOLA TESLA” ON SULPHUR DIOXIDE AIR POLLUTION IN BELGRADE

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ABSTRACT

In order to evaluate impacts of two major Serbian coal thermal power plants “Nikola Tesla A” (TENT A) and “Nikola Tesla B” (TENT B) on concentration of sulphur dioxide (SO_2) in Belgrade, the AERMOD modeling package is used. The main sources of SO_2 emissions in the city of Belgrade are traffic, heating power plants and individual fireboxes. TENT A and TENT B are the one of the largest coal thermal power plants in Serbia and in the Southeast Europe, and since the work without flue gas desulfurization (FGD) system, their influence on air quality in Belgrade is considerable. Two scenarios are analyzed in this study: Scenario 1(present situation without FGD) and Scenario 2 (future situation after installation of FGD). Results are presented on annual means [$\mu g\ m^{-3}$] plots. Estimated annual means concentrations of SO_2 in 2010, shows that contributions of examined power plants, depending on the part of the city, are 7.73 to 13.24[$\mu g\ m^{-3}$] for Scenario 1, and 1.36 to 2.34[$\mu g\ m^{-3}$] for Scenario 2. Considering that annual mean concentration of SO_2 in 2010 for city of Belgrade is 23[$\mu g\ m^{-3}$], it can be concluded that examined power plants have great influence on SO_2 concentration in Belgrade, and that installation of FGD will significantly contribute to better air quality in the city of Belgrade.

Key words: *thermal power plant, SO_2, AERMOD, modeling, FGD.*

INTRODUCTION

The air quality in the Republic of Serbia is mainly determined by the emissions of SO_2, NOx, CO, particulate matter and other pollutants which originate from thermal power plants (use of lignite and poor precipitation) and industrial plants. Air quality is especially aggravated during the weather conditions without wind and during the heating season.

Electricity in the Republic of Serbia is generated within the PE Electric Power Industry of Serbia.

Belgrade (population 1.6 million) is situated at the crossing of the communication paths between eastern and western Europe, on the Balkan Peninsula. It has grown around the banks of rives, the Sava and the Danube, at their confluence, and has average elevation of 116.75 m, with characteristics of hilly city. The Belgrade metropolitan area combines two different natural settings: the Pannonian Plain to the north and the hilly Šumadija to the south.

The climate is moderate continental, with four seasons; the average annual temperature is 11.9 C, January is the coldest month (average 0.4 C) and July the hottest (average 21.7 C); an annual average of 139 days with precipitation (annual average 667.9 mm). [3]

The SO_2 concentration in the city of Belgrade show very regular variability, with high concentration in winter (October-March), the cold season, and a gradual decrease to minimum values in summer. The analyses shown in [3] indicate that the maximum concentration of SO_2 in winter months is concentrated around the area with several poorly filtered large heating systems near the center of the city. In summer, the maximum is shifted more to the Industrial area near the Danube riverbank. The data show that the SO_2 values exceed the limit value only during the winter season, almost exclusively in the central city zones.

Since total estimated emissions of SO_2 from the plants of the PE Electric Power Industry of Serbia are 360,440 t/year, out of 81,707 t/year from TENT A and 50,110 t/year from TENT B [1], in this paper, we focus on influence of two coal fired power plants in the vicinity of Belgrade (Thermal Power Plant “Nikola Tesla A” and Thermal Power Plant “Nikola Tesla B”) on SO_2 concentration in this city. Since they use lignite as a fuel, those two power plants present major sources of SO_2 emission in this part of Serbia, as well. We evaluate present situation (Scenario 1) when plants operate without a system for flue gas desulfurization (FGD) and future situation (Scenario 2), according plans of PE Electric Power Industry of Serbia, when all existing units work with installed FGD, plus new additional unit B3 (744 MW) in Thermal Power Plant “Nikola Tesla B”.

SOURCE CHARACTERISTICS AND EMISSIONS

Scenario 1

Installed output of the thermal power plants (net output) is 5171 MW or 61.9% of total installed capacities of PE Electric Power Industry of Serbia. [1] The Thermal Power Plant “Nikola Tesla A” (TENT A) is the biggest in Serbia and in the Balkans, with six units totaling 1,690 MW of power. It is located in Obrenovac, a town of 70,000 inhabitans on the banks of Sava, about 30 km from Belgrade, and surrounded by Kolubara and Tamnava rivers. It is the biggest producer of electricity in the electric energy system of Serbia, with an average production of more than eight bilion kWh a year delivered to the consumers through a 400/220 KW transformer station. The Thermal Power Plant “Nikola Tesla B” (TENT B) is located on the right bank of the Sava River, 50 kilometers west from Belgrade and 17 kilometers upstream from TENT A complex. It has two largest power units in Serbia, with power of 620 megawatts each. [2] Units and stacks parameters of those power plants are shown in Table 1.

Table 1: Units and stacks parameters of TENT A and TENT B (Scenario 1) [4]

Plant	Unit	Capacity (MW)	Stack height (m)	Stack inner diameter (m)	Exit temp (°C)	Exit velocity (m/s)	SO_2 emission rate* (g/s)
TENT A	A1-A3	725	150	10.4	175	24.20	6328
	A4	308.5	220	6.3	175	33.24	3148
	A5	308.5	220	6.3	175	33.24	3148
	A6	348.37	220	6.3	175	33.24	3148
TENT B	B1	620	280	8	180	37.00	1870
	B2	620	280	8	180	37.00	1870

* Emissions rates are measured by authorized organization.

Scenario 2

In order to bring sulphur oxide emission in compliance with the requirements of the local and EU regulations PE Electric Power Industry of Serbia has prepared projects for installation of flue gas desulphurization plants in TENT A (excepting units A1 and A2) and TENTB. The technological-technical design for flue gas desulphurization, considered in the design, is based on the newest achievements in the area of wet FGD systems, which imply the use of limestone as a sorbent and generation of gypsum as a by-product. In accordance with the stipulations of the EU Directive 2001/80/EC, the FGD plants have been designed so as to fulfill the requirements related to the emission limit values for sulphur dioxide, being 400 mg/Nm3, which requires a process efficiency of 94%. [1]

Wet FGD (WFGD) technology, using limestone as a reagent, a wet scrubbing process, is the FGD technology most frequently selected for sulphur dioxide reduction from coal-fired utility boilers. The

Wet FGD process is considered a commercially mature technology and is offered by a number of suppliers.

The absorbers are situated after the TPP’s electrostatic precipitators (EPS). The raw flue gas, coming from the boiler and ESP’s, passes through the induce draft fans and booster fans before entering the absorbers for scrubbing. The scrubbed saturated gas is discharged to atmosphere through a new wet stacks. The WFGD System removes SO_2 by scrubbing the flue gas with limestone slurry. Flue gas is treated in an absorber by passing the flue gas stream through a limestone slurry spray. In absorber design, the gas flows upward through the absorber countercurrent to the spray liquor (limestone slurry) flowing downward through the absorber.

In a wet limestone scrubbing system, a complex series of kinetic and equilibrium controlled reactions occur in the gas, liquid and solid phases. These reactions may be expressed in this overall equation:

$$CaCO_3 + SO_2 + 2H_2O + \frac{1}{2}O_2 \rightarrow CaSO_4 \cdot 2H_2O + CO_2 \qquad (1)$$

Characteristics of the flue gas after desulphurisation process are significantly changed compared to the state before treatment at this system. In addition to the required reduction of sulphur oxide content, the flue gas is saturated with moisture, contains a certain amount of droplets (depending on the efficiency of mist eliminators), has a much lower temperature, and the reduced amount of fly ash particles and slightly higher concentration of carbon dioxide. [4]

Besides FGD systems, in order to as closely as possible evaluate a future impact of those power plants, in this study we consider emissions from future unit of TENT B (unit B3) as well.
Units and stacks parameters for Scenario 2 are shown in Table 2.

Table 2: Unit and stack parameters of TENT A and TENT B (Scenario 2) [4]

Plant	Unit	Capacity (MW)	Stack height (m)	Stack inner diameter (m)	Exit temp (°C)	Exit velocity (m/s)	SO_2 emission rate* (g/s)
TENT A	A1-A2	420	150	10.4	68	12.00	1816
	A3-A4	613.5	140	12.4	68	14.45	175
	A5-A6	656.87	140	12.4	68	14.45	175
TENT B	B1	620	230	10.5	68	17.42	157
	B2	620	230	10.5	68	17.42	157
	B3	744	210	9.5	68	18.05	144

* Emissions rates are measured by authorized organization.

DOMAIN AND MODELING APPROACH

The AERMOD modeling system was used to model the air quality impact of power plant emission. AERMOD is a steady-state plume model which calculates atmospheric dispersion based on the planetary boundary layer turbulence structure and on some scaling concepts, and can account for both surface and elevated sources. Moreover, it can be used in either simple (flat) or complex terrain scenarios. In the stable boundary layer, the dispersion is assumed to be Gaussian in both the vertical and the horizontal directions. In the convective boundary layer, the horizontal distribution is assumed to be Gaussian whereas the vertical distribution is described by a bi-Gaussian probability density function. AERMOD uses surface and profile meteorological data obtained from a single meteorological station. Alternatively, the extended version of its meteorological preprocessor, AERMET VIEW, can estimate the wind profile from the surface data. AERMOD incorporates a new approach to account for airflow and dispersion in complex terrain. Namely, where appropriate, the plume is modeled as either impacting on or following smoothly the terrain. This approach is physically realistic and simple to implement, and avoids the need to distinguish among simple, intermediate and complex terrain, as currently required in regulatory guidelines. Hence, the new version of AERMOD saves the need of defining complex terrain regimes, since the terrain in the study area is handled in a consistent and continuous manner. AERMOD’s terrain preprocessor, AERMAP, uses gridded elevation data to calculate a representative terrain-influence height, also referred to as the terrain height scale. The terrain height scale, which is uniquely defined for each receptor location, is used to calculate the dividing streamline height. The gridded data needed by AERMAP is obtained from a Digital Elevation Model (DEM), and the elevation of each specified receptor is automatically assigned through AERMAP. Specifically, for each receptor, AERMAP passes the following information to AERMOD: the receptor’s location, its height above the sea level, and the receptor specific terrain height scale. [5]

Procedure of modeling included the following procedures: 1. Preparation of facilities plan, including sources and facilities; 2. Defining the domain of model and the locations of the receptors; 3. Developing inventories of all observed sources; 4. Characterization of the types of sources; 5. Processing of required meteorological data; 7. The processing of the terrain data; 8. Modeling and analysis of results. Based on the input parameters of sources, emissions and meteorological data, modeling is obtained by the spatial distribution of ground level concentrations of selected pollutants.

Modeling for the present study included model domain of 50 km x 50 km, with TENT A in its center, Fig. 2, or an area of 2500 km^2. Cartesian coordinate system with the distance of 400m between adjacent points (receptors) is used, which means that the models processed 15876 points (receptors). To obtain necessary terrain data, we have used SRTM3 - Shuttle Radar Topography Mission data (resolution: ~ 90m, 3 arc-sec).

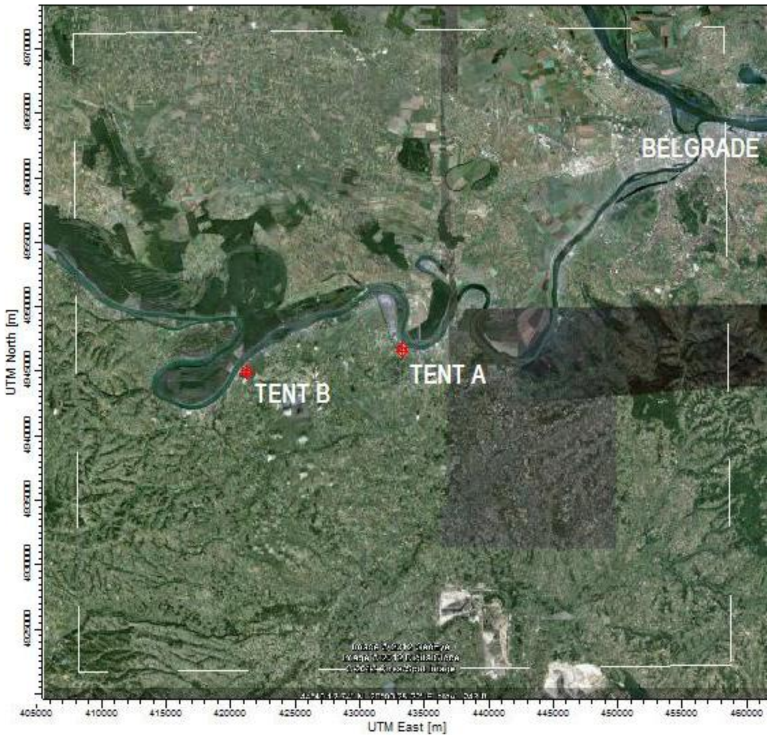

Figure 1. Model domain and locations of power plants

AERMET, a meteorological preprocessor, prepares hourly surface data and upper air data for use in AERMOD. The surface data are hourly observations of surface level parameters such as wind speed, temperature, and cloud cover that are used by AERMET to generate a surface file for use in AERMOD. The upper air data file provides information on the vertical structure of the atmosphere. This includes the height, pressure, dry bulb temperature, and relative humidity. Meteorological data that we used for the preparation of model include hourly values of: wind speed, wind direction, ambient temperature, relative humidity, atmospheric pressure, cloud cover-opaque. Since upper air data was not available, AERMET Upper Air Estimator is used. Meteorological data for the year 2010 were obtained from the Serbian Environmental Protection Agency (SEPA). The closest meteorological station to the power plants are *Obrenovac-Deponija pepela*. Fig. 2 demonstrates wind rose and frequency analysis, based on meteorological data from *Obrenovac - Deponija pepela* for 2010.

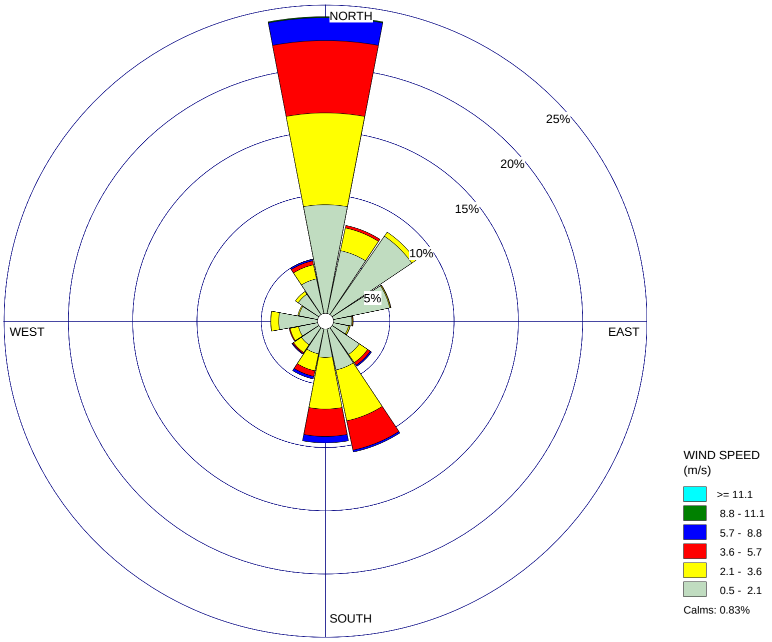

Figure 2. Wind rose and frequency analysis, based on meteorological data from Obrenovac - Deponija pepela for 2010

As buildings could radically influence the dispersion of pollutants there is need for building downwash analysis. Fig. 3. shows 3D models of TENT A and TENT B with all sources (red stacks) for Scenario 1 and Scenario 2.

TENT B (Scenario 1) TENT B (Scenario 2)

TENT A (Scenario 1) TENT A (Scenario 2)

Figure 3. 3D models of TENT A and TENT B with all sources (red stacks)

RESULTS AND DISCUSSION

Considering that these models are not taken into account background pollution, presented average annual plots do not represent air quality (SO_2 concentration) in the models domain area, but only the contribution of the power plants to overall air quality in Belgrade. It is very important to note that these models represent the worst case scenarios, consider that all pollutant sources emit maximum emission rate 24 hours a day, 365 days a year, which is certainly not the case.

Since the annual mean concentration of SO_2 in 2010 for Belgrade is 23 μg m^{-3} [6], results for Scenario 1 (Fig. 4.) show that TENT A and TENT B have high influence on SO_2 concentration in the city. Depending on the part of the city, that contribution goes from 13.24 to 7.73 μg m^{-3}. West parts of Belgrade are more exposed to the SO_2 emissions from power plants sources, and there, according presented plots could be observed the highest concentrations of SO_2. Clear decreasing trend of SO_2 concentrations could be observed from western to eastern parts of the city.

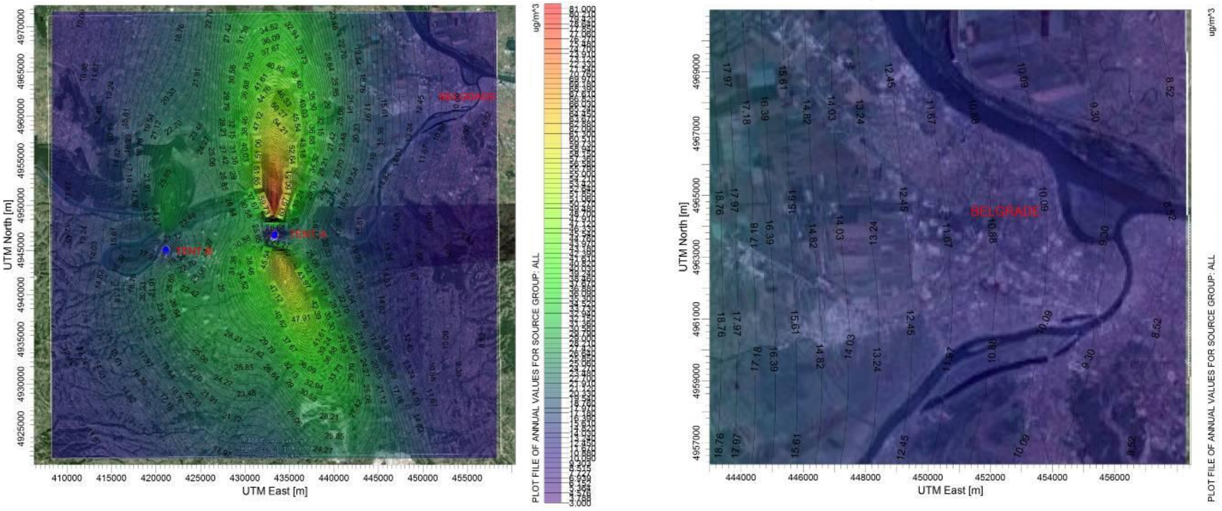

Figure 4. Annual mean concentration of SO_2 in 2010 (Scenario 1)

According the data presented in Table 1. and Table 2., overall emissions for Scenario 2 presented only 13.5% of total emissions from Scenario 1, although Scenario 2 includes additional unit B3. That high difference in emissions and difference in source characteristics is reflected on spatial distribution. Annual mean concentration of SO_2 in 2010 for Scenario 2 is presented on Fig.5. Decreasing SO_2 emission from TENT A and TENT B, as a result of installed FGD technology, brings almost 6 times less contribution of SO_2 pollution in Belgrade. The similar way of distribution and decreasing trend of SO_2 could be observed for Scenario 2 as well as for Scenario 1. In this case, again depending on the part of the city, contribution goes from 1.36 to 2.34 μg m^{-3}. Decreasing trend follows west - east direction.

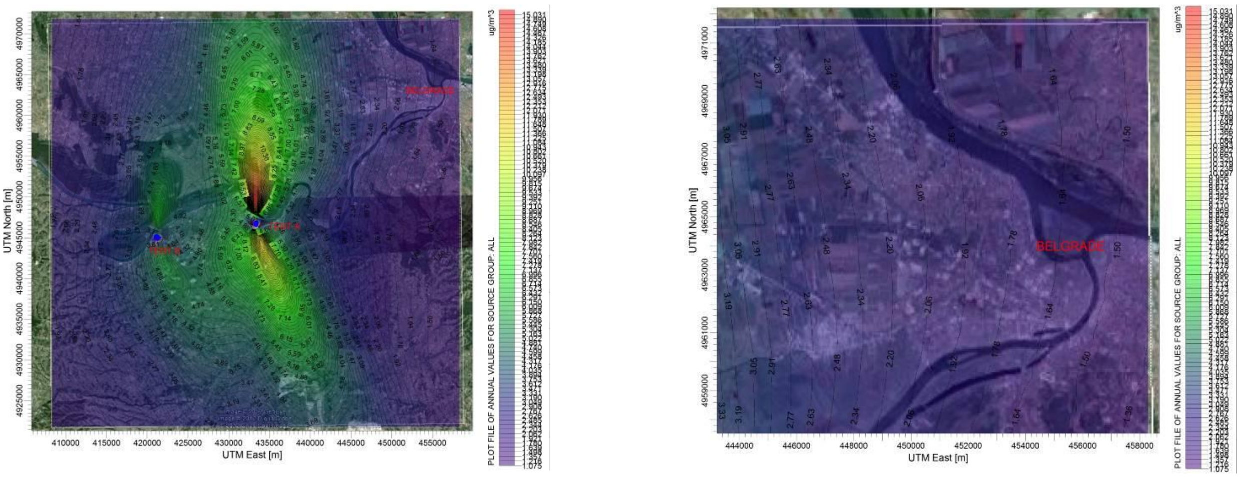

Figure 4. Annual mean concentration of SO_2 in 2010 (Scenario 2)

CONCLUSION

This study shows the evaluated impact of two major Serbian coal thermal power plants "Nikola Tesla A" (TENT A) and "Nikola Tesla B" (TENT B) on concentration of sulphur dioxide (SO_2) in Belgrade. AERMOD modeling package is used to estimate the contribution of this influence. Through two scenarios, this study presented presence influence, and most possible future influence which take into account installation of FGD system and new unit B3 (744 MW). Estimated annual means concentrations of SO_2 in 2010, shows that contributions of examined power plants, depending on the part of the city, are from 7.73 to 13.24 $\mu g\ m^{-3}$ for Scenario 1, and from 1.36 to 2.34 $\mu g\ m^{-3}$ for Scenario 2. Considering that annual mean concentration of SO_2 in 2010 for city of Belgrade is 23 $\mu g\ m^{-3}$, it can be concluded that examined power plants have great influence on SO_2 concentration in Belgrade, for present situation. Installation of FGD technology will not only bring compliance with the requirements of the local and EU regulations, but it will significantly contribute to better air quality in the city of Belgrade.

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