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CALCULATION AND ANALYSIS OF AIR EMISSION FROM FUTURE THERMAL POWER PLANT USING GASEOUS FUELS IN ZENICA

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ABSTRACT
The calculation and analysis of potential air emissions of SO_2, NO_x, and particulate matter from the planned power plant in Zenica in which process gases (blast furnace and coke oven gas) and natural gas will be burned, are given in this paper. Given the state of air quality in Zenica valley and considering the size of the pressure on the environment, especially on the quality of air, generated by thermal power plants, the goal is to quantify emissions of major pollutants from new thermal power plant. The emission calculation was done using the EMEP/EEA methodology the European Environment Agency, is used for estimation of air emissions from new thermal power plant for three potential scenarios of use of gaseous fuels. According to the results of the calculation, the SO_2 emission from the planned thermal power plant is around 195 t/y, the NOx emission ranges from 357 to 506 t/y, and the particulate emission is about 2.1 t/y for all three fuel balance scenarios. In all three scenarios, SO_2 emission is lower by 4.331 t/y (95.69%), NOx emission is lower by 284.7 to 135.5 t/y (44.37-21.11%), and particle emission by 234.8 t/y (99.1%) compared to the existing coal-fired power plant. It can be concluded that scenario A is the most acceptable on the basis of emission reductions because the scenario has the lowest NOx emission, and the emissions of the other two pollutants do not have significant differences.
Keywords: air emission, emission estimates, thermal power plants

1. INTRODUCTION
Finding solution for air pollution in urban areas is one of the most important challenges that the world is currently facing with, when it comes to environmental protection and health protection. According to the continuous monitoring of air quality, the air in the town of Zenica is excessively polluted and falls into the third quality class [1, 2]. Air in Zenica is polluted because of present emissions of harmful substances from metallurgical and thermal power plants. Thermal power plant significantly affect the quality of ambient air due to high emissions in the around the plant, and create a lot of pressure in the local ecosystem [3]. Emissions from power plants depend on the type and quality of used fuel. In the existing hotplates dominantly burns coal with high sulfur and dust content and in combination with gaseous fuel. The burning of coal emits a lot harmful pollutants, such as CO_2, SO_2, NO_x, CO, and solid particles. Coal is considered as a fossil fuel whose combustion produces high pressure on all elements of the environment, and in particular on air [4, 5]. Production of one GJ of steam in thermal power plants using coal produces about 1361 g of SO_2, 183 g of NO_x, 3254 g of solid particles and 101 000 g of CO_2. On the other hand, production of a GJ of steam in power plants burning gaseous fuels emit around 0,68 g of SO_2, 93,3 g of NO_x, 0,1 g of solid particles and 56 100 g of CO_2 [6].
Gaseous fuels have certain advantages compared to solid and liquid fuels, when used in industry and other sectors. The combustion of gases does not produce smoke and ash, and environmental pollution is reduced to a minimum, given that it is relatively easy to remove impurities and sulfur compounds (most commonly hydrogen sulphide) from gaseous fuels, and combustion products do not contain oxides of SO_2 and SO_3. Also, it is easy to change the ratio of gas/air and the way of mixing of gases prior to their combustion, and thus the temperature of combustion can be regulated. The temperature of combustion is the most important for formation of nitrogen oxides during combustion. [7]

Given the above mentioned facts and the condition of air in Zenica valley, it is of great importance to estimate emissions from new thermal power plant to gaseous fuel (coke, blast-furnace and natural gas) to analyze them in relation to those from the existing thermal power plant, which is the subject of this paper.

2. METHODOLOGY OF PAPER

Determination of the emission according to the measurement results, especially continuous ones, is the most accurate and in most cases the most reliable method of determining air emissions, and as such is recommended as a first choice and as the most reliable [8, 9].

Air emissions from existing thermal power plant are determined on the basis of continuous monitoring of emissions installed on the chimney of the plant. The planned plant is not yet built, and therefore it is not possible to use this method in determination of emissions from the future power plant. Instead, European Monitoring and Evaluation Program (EMEP) / Europe Environmental Agency (EEA) methodology, formerly called CORINAIR (CORe INventory of AIR emissions) is used. This methodology is primarily designed for making of national registries of emissions, but it is also used in the assessment of air emissions from plants that are planned to be built. It uses emission factors, practically or theoretically derived numerical values which compounded with other relevant parameters can give annual emission [9].

3. AIR EMISSION OF SO_2, NO_x AND SOLID PARTICLES FROM THERMAL POWER PLANT ON THE GASEOUS FUEL

According to the technological process, it is envisaged that the new thermal power plants will primarily burn 83,400 m^3/h (730,584,000 m^3/year) of blast furnace gas and 12,400 m^3/h (108,624,000 m^3/year) of coke oven gas, and optionally 2 500-5 000 m^3/h (21,9 to 43,8 million m^3/year) of natural gas. Therefore, three possible scenarios of fuel consumption are considered in the calculation of emission in this paper:

- Scenario A: the maximum planned amounts of blast furnace gas and coke oven gas are used,
- Scenario B: the maximum planned amounts of of blast furnace gas and coke oven gas, and 2500 m3/h of natural gas are used,
- Scenario C: the maximum planned amounts of of blast furnace gas and coke oven gas, and 5000 m3/h of natural gas are used.

For the calculation of potential emissions from the new thermal power plant, the number of 8 760 working hours per year was assumed. Excess air coefficient are $\lambda=1.00$ for the blast furnace gas, $\lambda=1.25$ for coke oven gas and $\lambda=1.1$ for natural gas. Based on this information and the chemical analysis of the fuel given in Table 1, 2, and 3, the following values of volume of flue gases were obtained.

- furnace gas - 1.4433 m^3/m^3
- coke gas - 5.0823 m3/m^3, and
- natural gas - 11,4535 m^3/m^3.

Table 1. Chemical composition of blast furnace gas

	CO_2	O_2	H_2	N_2	CO
%	18, 39	0, 40	2, 53	56, 62	22, 06

Table 2. Chemical composition of coke oven gas

	CO_2	C_3H_6	H_2	O_2	N_2	CH_4	CO	H_2S
%	1, 57	2, 94	62, 82	0, 30	4, 85	23, 20	4, 32	0, 36

Table 3. Chemical composition of natural gas in B&H [18]

	CH_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	CO_2
%	96, 2	1, 2	0, 3	0, 2	1, 8	0, 3

The parameters required for calculation of potential emissions of certain pollutants from planned thermal power plant, are given in Table 4.

Table 4. The parameters for calculation of air emission from new thermal power plant

Parameter	Unit	Fuel		
		Blast furnace gas	Coke oven gas	Natural gas
The quantity of fuel (B)	m^3/year	730 584 000	108 624 000	(21 900 000*) (43 800 000**)
Content of sulfur (Cs)[1]	g/m^3	0,045	8	0,0075
Lower calorific value (Hd)	kJ/m^3	3 081	17 631	34 075,6
FE_{NOX}[2]	g/GJ	65	110	100
FE_{TSP}[3]	g/GJ	5	5	0,9
$\eta_{desulphurization}$[4]	-	0, 9		
β[4]	-	0, 99		

* Consumption of natural gas according to scenario B.
** Consumption of natural gas according to scenario C.
[1] Table C-1 EMEP-EEA air pollutant emission inventory guidebook-2016,
[2] Table 24. EMEP-EEA air pollutant emission inventory guidebook-2016,
[3] Table 8.2d and 8.2e EMEP-EEA air pollutant emission inventory guidebook-2016,
[4] Table 7. EMEP-EEA air pollutant emission inventory guidebook-2013 for wet scruber.

Using the values of sulfur content in the analyzed gaseous fuels, the efficiency of desulfurization and the availability of desulfurization measure for the wet scrubber, all given in Table 4, the following factors of sulfur dioxide were obtained: 98.91 g/GJ for coke oven gas, 3.18 g/GJ for blast furnace gas, and 0.048 g/GJ for natural gas. Using calculated and selected emission factors, the annual air emissions for SO_2, NO_x and solid particles were calculated. These values are shown in Table 5. The calculated volumes of flue gases for all three scenarios are also given in Table 5.

It needs to be noted, that in calculation of air emission of SO_2, η was taken as 0 because it is has been already taken into account in calculation of emission factors. For NOx, no secondary measures were planned, so its emission were calculated with η=0. Wet desulphurization reduces the emission of particulate matter and its efficiency depends on the particle size [10]. For the particle size of 10 microns efficiency is around 0.99, but considering that in the calculation given in this paper, the worst possible case values were used, the calculation of solid particles was carried out with the degree of efficiency of the dusting of η = 0.9.

Table 5. Calculated annual air emission from new thermal power plant

	Volume of flue gases		Emission (kg/g)		
	m^3/year	m^3/h	SO_2	NO_x	Solid particles
Scenario A	1 606 511 642	183 391	195 034, 1451	356 976, 8766	2 083, 04
Scenario B	1 857 341 102	212 025	195 069, 9600	431 602, 4110	2 150, 20
Scenario C	2 108 170 562	240 659	195 105, 7856	506 228, 0100	2 217, 37

Using the calculated values of the emission of pollutants and the volume of flue gas given in Table 5, emission of SO_2, NO_x, and solid particles in mg/m^3 was calculated. These values are given in Table 6.

Table 6. Air emission from new thermal power plant

	Emission (mg/m^3)		
	SO_2	NO_x	Solid particles
Scenario A	121, 402	222, 206	1, 296
Scenario B	105, 026	232, 376	1, 157
Scenario C	93, 547	240, 126	1, 052

It be seen that the addition of natural gas reduces the concentration of SO_2 and solid particles in the waste flue gases, while NO_x concentration increases. Due to the chemical composition of natural gas, it acts as a "diluent" in terms of SO_2 and solid particles, and increases emission of NO_x due to the formation of, so called thermal NO_x.

4. COMPARATIVE ANALYSIS OF AIR EMISSION FROM EXISTING AND THERMAL POWER PLANT ON THE GASEOUS FUEL

The main goal of building a gas-fired power plant is the stable production of heat energy for the technological needs of the metallurgical plants and the heating of the city of Zenica while simultaneously reducing the air emissions compared to the existing thermal energy in order to improve the quality of the surrounding air in the city of Zenica. The emission values of existing and planned thermal power plant for three scenarios are given in Table 7, respectively.

Table 7. Comparative analysis of air emission from existing and planned thermal power plant for three scenarios of fuel consumption

Pollutant	Scenario A		Scenario B		Scenario C		Existing plant	
	mg/m^3	kg/year	mg/m^3	kg/year	mg/m^3	mg/m^3	mg/m^3	kg/year
SO_2	121,402	195 034,15	105,026	195 069,96	93,547	195 105,79	2 289,135	4 525 989,95
NO_x	222,206	356 976,88	232,376	431 602,41	240,126	506 228,01	333,177	641 699,36
Solid particles	1,296	2 083,04	1,157	2 150,20	1,052	2 217,37	123,298	236 970,83

Based on data shown in Table 7, it can be clearly concluded that the emissions of pollutants from the planned thermal power plant burning gaseous fuels in all three scenarios produce lower emissions than the existing power plant in which coal, blast furnace gas, coke oven gas and natural gas are burned. Scenario A provides the lowest emission of analyzed pollutants

5. CONCLUSION

Based on the results showed in previous chapters, it can be concluded that in all three scenarios annual emission of SO_2 from future thermal power plant is 95.69% lower (4,331 t/y), of solid particles 99.1% lower (234.8 t/y) than emission of these two pollutants from existing power plant. The NOx emissions are lower by 44.37% (284.7 t/year) in scenario A, 32.74% or 210, 1 t/year in scenario B and 21.11% or 135.5 t/year in scenario C. These data are very important because they indicate that significant reduction of emissions of SO_2 and particulate matter will happen. The values of this two pollutants in ambient air in the area of Zenica valley are significantly higher than the limit values. This means that the realization of the project of building of new thermal power plant, is expected to significantly improve air quality in Zenica, at least on the basis of the two pollutant. Quantification and analysis of the impact of the planned thermal power plants burning gaseous fuels on the quality of ambient air is not the subject of this paper, but it is certainly a suggestion for further research, which would complement the analysis of the impact of the new thermal power plant on the air.

6. REFERENCES

[1] Goletić Š. et al.: Kantonalni ekološki akcioni plan Zeničko-Dobojskog kantona za period 2017.-2025. godina, Univerzitet u Zenici, Metalurški institut „Kemal Kapetanović“, Zenica, 2016.

[2] Goletić Š., Imamović, N.: Monitoring of air quality in Zenica valley, 15th International Research/Expert Conference ”Trends in the Development of Machinery and Associated Technology”, TMT 2011, Prague, Czech Republic, 12-18 September 2011.

[3] Pokale W. K.: Effects of thermal power plant on environment, Scientific Reviews and Chemical Communications 2 (3), 212-215, 2012.

[4] Li D., Guo Y, Li Y., Ding P., Wang Q., Cao Z.: Air Pollutant Emissions from Coal-Fired Power Plants, Open Journal of Air Pollution, 1, 37-41, 2012.

[5] Duraković J., Goletić Š.: Primjena tehničko – tehnoloških mjera na termoenergetskim postrojenjima u cilju smanjenja emisije SO_2, Regionalna konferencija: Industrijska energetika i zaštita životne sredine u zemljama Jugoistočne Evrope IEEP 2008, Zlatibor, Serbia, 24-27. juni 2008.

[6] Barbir F.: Utjecaj termoenergetskih postrojenja na okoliš, 2011.: http://marjan.fesb.hr/~fbarbir/PDFs%20Termoenergetska%20postrojenja/12%20Utjecaj%20na%20okolis (april, 2017.)

[7] Neimarlija N.: Fosilna goriva, procesi sagorijevanja i okolinski aspekti, Univerzitet u Zenici, Zenica, 2007.

[8] Agencija za zaštitu okoliša: Priručnik za vođenje registra onečišćenja okoliša, Tiskara HiP, Zagreb, 2008.

[9] European Environment Agency: EMEP/EEA air pollutant emission inventory guidebook 2016, 1.A.1. Energy industries, Luxembourg: Publications Office of the European Union, 2016.

[10] US EPA: Wet Scrubbers for Particulate Matter, 2002.: https://www3.epa.gov/ttncatc1/dir1/cs6ch2.pdf (april, 2017.)