Professional paper

UDK 628.47:66.074.37(497.6)
DOI 10.7251/COMEN2601100D

ANALYSIS OF THE EFFICIENCY OF THE FLUE GAS DESULFURIZATION PROCESS AT THE UGLJEVIK MINE AND THERMAL POWER PLANT

Jelena Dabić[1*], Jelena Vuković[2], Nebojša Vasiljević[2], Slavko Smiljanić[2]

[1] Public Institution "Agricultural and Medical School" Bijeljina, Bijeljina, Republic of Srpska, B&H
[2] University of East Sarajevo, Faculty of Technology Zvornik, Zvornik, Republic of Srpska, B&H

[*] Corresponding author: jelenaddabic@gmail.com

Abstract: The flue gases from coal fired thermal power plants, contain combustion gases (SO_2, NO_x, CO, CO_2) and fine particles of fly ash. The concentration of sulfur oxides in the flue gas depends on the sulfur content in the coal. The flue gas desulfurization (FGD) process at TPP Ugljevik utilizes a wet scrubbing method, where a limestone suspension serves as the absorbent medium for sulfur oxides, with gypsum as a byproduct. Comparative analysis of emission levels before and after the FGD system installation indicates that the applied desulfurization technology is highly effective. The efficiency of the desulfurization plant ranged from 83.91% to 100%, depending on the inlet concentration of SO_2 in the flue gas. Estimates show that the FGD plant, depending on the intensity of operation, can annually remove between 7,000 and 55,800 tons of sulfur, with by-product gypsum production ranging from 3,660 to 29,280 tons. The implementation of this flue gas purification process significantly reduces the impact on the environment and ambient air pollution caused by sulfur oxides. For economic reasons, the plant is unfortunately unable to operate continuously.

Keywords: Flue gases, SO_2 emissions, desulfurization, wet scrubbing process.

1. INTRODUCTION

Air pollution is the presence of harmful substances in the atmosphere that adversely affect human health and the ecosystem. The basic pollutants that enter the atmosphere from various sources include sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), PM10 and PM2.5 particles, as well as heavy metals and organic pollutants [1]. One of the main problems when burning coal, with a high sulfur content, in thermal power plants is the emission of gaseous pollutants and particles. The main gaseous pollutants are sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide and carbon dioxide. Sulfur oxides originate from the oxidation of sulfur present in coal, and their release into the atmosphere causes a number of negative consequences for the environment and human health (acid rain, deterioration of air quality, degradation of ecosystems, corrosion of materials, plant extinction, respiratory and cardiovascular problems in humans, etc.) [2]. For this reason, great efforts are being made to limit their emissions. One of the most commonly used ways to limit sulphur oxide emissions is to desulphurize flue gases before they are released into the atmosphere [3], which brings significant environmental and health benefits. Also, a solid by-product of the desulfurization process - gypsum, can be widely used in the construction industry, agriculture and other fields, further reducing waste and improving the sustainability of this process. However, the implementation of the desulphurization process requires significant financial investments, and the process itself can generate wastewater and sludge that must be adequately treated so as not to endanger the environment. Also, the production and transportation of sorbents, such as limestone, can have additional negative environmental impacts, including carbon dioxide (CO_2) emissions that occur during the thermal treatment of limestone. Despite these challenges, flue gas desulphurization is considered an environmentally friendly solution that significantly contributes to reducing air pollution and protecting human health, while the negative effects of this process can be minimized by applying adequate by-product management technologies [4].

The aim of this paper is to analyze the flue gas desulphurization process in the Ugljevik Mine and Thermal Power Plant and to determine the desulphurization efficiency.

2. UGLJEVIK MINE AND THERMAL POWER PLANT

The Ugljevik Mine and Thermal Power Plant are located in the northwestern part of the Republic of Srpska, in the settlement of Ugljevik. The main activity of the Ugljevik Mine and Thermal Power Plant is the production of electricity and the exploitation and sale of lignite coal. Within this enterprise, there are two operational units: the Mining Unit-Surface Mine and the Thermal Power Plant Unit. The settlement of Ugljevik is situated on the slopes of the Majevica mountain in the valley of the Janja' river, at an altitude of 158 meters. The municipality has about 16,000 inhabitants. The Ugljevik Thermal Power

Figure 1. Geographical location of the Ugljevik Thermal Power Plant

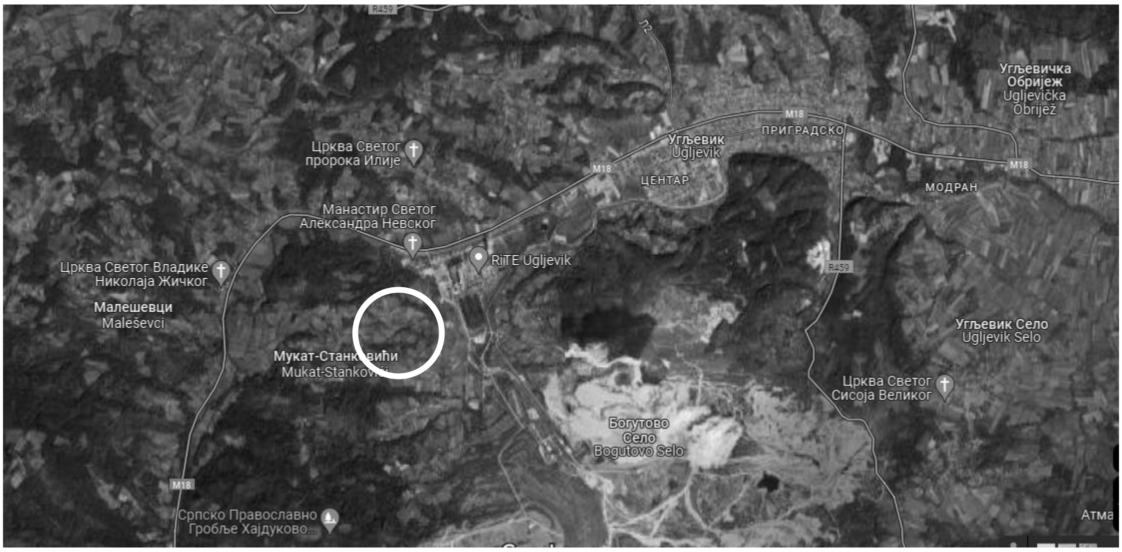

Figure 2. Satellite image of the micro-location of the Ugljevik Thermal Power Plant

Plant is located about 30 km from the Drina River and the border with the Republic of Serbia. The position of the Ugljevik Thermal Power Plant and the micro location of the facility are shown in images number 1 and 2.

The Ugljevik Thermal Power Plant started operating in 1985 with an estimated aimed annual production of 1601 GWh. It is a significant energy facility in Bosnia and Herzegovina and the largest generator of electricity in the Republic of Srpska, supplying a large part of the country with electricity. The Ugljevik Thermal Power Plant uses brown coal as its main fuel, which is extracted from the open-pit mine Bogutovo Selo, with a pre-estimated annual production of 1,750,000 tons. The brown coal from this location has a very high sulfur content (5-6%), and its calorific value ranges from 10,000 to 13,000 kJ/kg. The chimney of the Ugljevik Thermal Power Plant, standing 310 meters high, allows for efficient emission discharge and dispersion of pollutants into the atmosphere, thereby reducing the impact on the local environment.

2.1. Desulfurization of Flue Gases from the Ugljevik Thermal Power Plant

Air and environmental protection is a standard that must be met today, and it was the main reason for starting the project to build a flue gas desulphurization plant at the Ugljevik Thermal Power Plant. The construction of the flue gas desulfurization plant and the installation of electrostatic precipitators to reduce particle emissions lasted from 2017 to 2020, when the plants were put into operation.

The process of flue gas desulfurization from the Ugljevik Thermal Power Plant is very simple and is based on the contact of the flue gas with a limestone suspension. The process begins with dedusting of flue gases in an electrostatic precipitator. The dedusted flue gas is directed to the flue gas fans and booster fans, and then it is taken to the absorber where it is purified. The flue gas is introduced into the absorber in the lower part and flows upwards, coming into contact with the sprayed limestone suspension, which falls downwards from several spraying levels. At the entrance to the absorber, the flue gas cools rapidly in contact with water, then the water from the flue gas evaporates and it becomes saturated with moisture at the very exit from the absorber, where its temperature is 65ºC. Then the flue gas thus purified is released into the air through the chimney. Figure 3 shows the flow diagram in the flue gas desulfurization process at the Ugljevik Thermal Power Plant.

The basic chemical equations that take place during the wet flue gas desulfurization are:

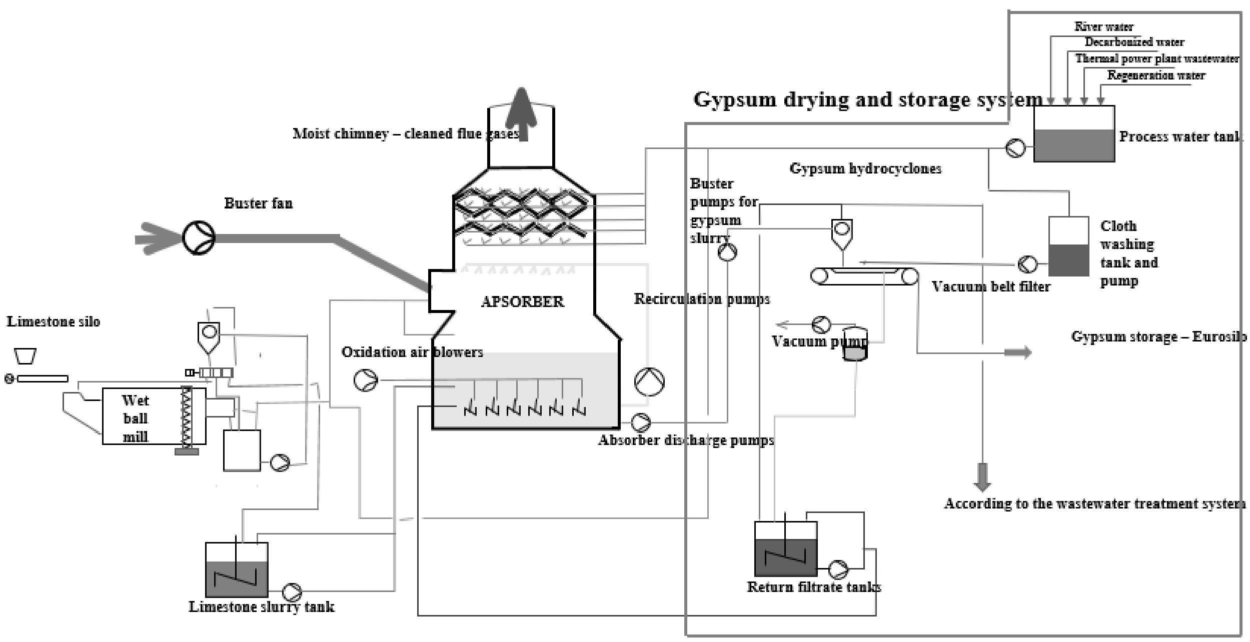

Figure 3. *Flow diagram in the flue gas treatment plant at the Ugljevik Thermal Power Plant*

- hydrolysis of sulfur dioxide:
  $SO_2 + H_2O \rightarrow H_2SO_3$
- dissolution of product of hydrolysis:
  $H_2SO_3 \rightarrow H^+ + HSO_3^-$
- dissolution of limestone:
  $CaCO_3 + H_2O \rightarrow HCO_3^- + Ca^{2+} + OH^-$
- formation/formation of sulfite:
  $Ca^{2+} + SO_3^- \rightarrow CaSO_3$ (sulfite)
- oxidation reaction:
  $2CaSO_3 + O_2 \rightarrow 2CaSO_4 \rightarrow CaSO_4 \cdot 2H_2O$

The basic technological equipment used in the FDG process at the Ugljevik Thermal Power Plant consists of:

- Absorber
- Absorber recirculation pumps
- Sprayers
- Drop Eliminators
- Oxidizing air blower
- Mixer

The main equipment for receiving, storing and preparing limestone suspension consists of:

- Reactors for reception and preparation of suspension.
- Suspension mixing systems to ensure uniform distribution of particles.
- Tanks for storing the prepared suspension, which is used in the desulfurization process.

This equipment ensures the efficient functioning of the desulfurization system and enables a continuous process of production and storage of by-products. [5].

Absorber represents the basic unit of the wet flue gas desulfurization system. Modern practice recognizes different types of absorbers, but in the context of the Ugljevik Thermal Power Plant, a countercurrent absorber is used, which is the most suitable for this plant. The countercurrent absorber enables optimal efficiency in the desulfurization process.

Recirculation pumps play an important role in the desulfurization process because they are used to recirculate the limestone suspension from the absorber tank towards the spray nozzles, where it is dispersed into fine droplets and thus brought into uniform contact with the flue gas stream. The main function of dispersion in the absorber is the uniform distribution of the limestone suspension throughout the entire interior of the absorber. The suspension droplets absorb SO_2 from the flue gas via a reaction that takes place between SO_2 and reagents, i.e. of the sorbent from the suspension. Hydrogen chloride (HCl), which is present in the flue gas, is also absorbed and neutralized by reacting with limestone, forming soluble salts, which leads to the accumulation of chloride ions in the process slurry. The mixer is the last part of the main equipment for flue gas desulfurization (FGD). Its main function is to mix the suspension in the absorber tank to prevent particle sedimentation and provide efficient oxidation. During the desulphurization process itself, by-products are created, such as gypsum, limestone, sometimes water and CO_2, depending on the applied desulfurization system. Gypsum is formed during the flue gas desulphurization process by calcium carbonate ($CaCO_3$) in limestone reacts with sulfur oxides (SO_2) in flue gases, creating calcium sulfate ($CaSO_3$), which is less harmful and can be disposed of or used in the production of gypsum [5,6].

Droplet eliminators are used to prevent acidic water droplets from being carried along with flue gas and released into the atmosphere. An oxidation air blower is used to introduce air into the absorber tank, whose basic function is to provide the necessary air for the oxidation of absorbed SO_2 into gypsum ($CaSO_4 \cdot 2H_2O$). This oxidation is crucial for the further processing process and the reduction of harmful gas emissions [7].

In the flue flow system, there is also equipment for continuous monitoring of flue gas emissions, including containers with emission data analysis equipment (CEMS). CEMS (Continuous Emission Monitoring System) stands for technology for continuously monitoring the concentration of pollutants in flue gases, such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which enables monitoring compliance with environmental standards.

The success of reducing sulfur dioxide emissions (SO_2) by the wet flue gas desulfurization process at the Ugljevik Coal Power Plant largely depends on the ratio of the amount of suspension dispersed in the absorber in relation to the amount of treated flue gas. This relationship is called the relationship between the liquid and gaseous phases, i.e. L/G (liquid-to-gas (L/G) ratio). A higher value of the ratio of liquid to gaseous phase (L/G) enables a more efficient reduction of SO_2 emissions, because then the flue gas is treated with a larger amount of absorbing liquid [1].

3. EXPERIMENTAL PART

When collecting data on desulphurization, two types of devices were used: the modern flue gas analyzer Testo 300, and the hand-held combustion product gas analyzer IMR 1000. The obtained data were subjected to statistical data processing in the SPSS 20.0 application program. [8]. Non-parametric data processing procedures were used, that is, the Chi-square test was used.

To calculate the efficiency of desulfurization, the following formula was used:

$$\text{Efficiency} = \frac{Ci - Ce}{Ci} \cdot 100\% \quad (1)$$

Where:

C_i (mg/Nm^3) – input concentration of SO_2 in the flue gas;

C_e (mg/Nm^3) – outlet concentration of SO_2 after treatment.

4. RESULTS AND DISCUSSION

The flue gas desulphurization process at the Ugljevik Thermal Power Plant has been carried out since August 2020. Desulphurization is based on a wet process, and enables efficient reduction of SO_2 emission into the air. Thanks to the construction of the FGD plant, the excess of SO_2 emission was prevented into the air.

The efficiency of the FGD system in the Ugljevik Thermal Power Plant largely depends on the type of absorber and the efficiency of the equipment used in the process, such as recirculation pumps, droplet eliminators and mixers. So, for example, recirculation pumps, which enable the recirculation of the limestone suspension through the absorber, are crucial for the even distribution of the suspension and the efficient absorption of SO_2 from flue gas. Recirculation enables optimal contact between the liquid and gaseous phases, thus improving the efficiency of the process [6]. These pumps, along with slurry atomizing nozzles, help to form fine droplets, thereby increasing the contact surface between the slurry and the flue gas, allowing for better pollutant removal.

Research conducted at the Ugljevik Thermal Power Plant shows that the countercurrent absorber is the most effective for the desulphurization process, as it enables optimal mass transfer between the gaseous and liquid phases. Thanks to the countercurrent movement of the gaseous and liquid phases, this type of absorber enables more efficient mass transfer and reduces the required height of the absorber.

SO_2 oxidation process into gypsum is crucial for reducing the emission of harmful gases. This process enables conversion of SO_2 into harmless compounds, reducing emissions into the atmosphere and contributing to achieving environmentally acceptable performance of the desulphurization system [5].

The analysis of by-products in the desulfurization process, such as gypsum and unused limestone, requires their proper storage and further processing. Gypsum, which is produced as an end product of desulfurization, is used in the construction industry, while unused limestone can be recycled and reused in the process.

By reviewing data on SO_2 emissions shown in *Tables 1 - 6* measured during the period when the FGD plant at the Ugljevik Thermal Power Plant was in operation, a clear picture of the efficiency of this process is obtained. Based on the presented data, it can be concluded whether and to what extent the FGD process at the Ugljevik Thermal Power Plant is successful. The values for the efficiency of plant operation and the amount of separated sulfur refer to the period when the plant was active, because the plant has not worked continuously since its commissioning. The reason for this is the high consumption of electricity, which, despite its efficiency, makes it economically unsustainable. In order to compare the efficiency of the flue gas desulphurization system at the Ugljevik Thermal Power Plant, tables 1 - 4 show the daily concentrations of SO_2 in the flue gas before and after the desulfurization process, for the months of August in the period 2020-2023. These data enable a more detailed analysis of the performance of the desulfurization system in that period.

Table 1. *Sulfur dioxide concentrations in flue gas before and after treatment and desulfurization efficiency, for the month of August 2020*

Date	Emission SO_2 mg/Nm^3		Plant efficiency (%)
	1 – influent	2 – effluent	
1.8.2020	**14965,73**	127,60	99,14
2.8.2020	14097,71	82,79	99,41
3.8.2020	12464,13	111,08	99,10
4.8.2020	13219,38	140,40	98,93
5.8.2020	14552,92	115,25	99,20

Date	Emission SO_2 mg/Nm^3		Plant efficiency (%)
	1 – influent	2 – effluent	
6.8.2020	13073,70	112,77	99,13
7.8.2020	14401,84	161,66	98,87
8.8.2020	13005,33	**2091,50**	**83,91**
9.8.2020	14340,98	119,60	99,16
10.8.2020	13078,50	155,22	98,81
11.8.2020	14780,75	106,98	99,27
12.8.2020	14362,48	190,00	98,67
13.8.2020	13426,15	84,53	99,37
14.8.2020	13879,77	107,79	99,22
15.8.2020	14738,73	108,21	99,26
16.8.2020	14738,74	114,22	99,22
17.8.2020	14818,81	145,89	99,01
18.8.2020	14474,99	142,02	99,01
19.8.2020	14297,36	138,86	99,02
20.8.2020	14028,83	80,71	99,42
21.8.2020	0	74,64	0
22.8.2020	13310,90	74,64	99,43
23.8.2020	13959,80	115,51	99,17
24.8.2020	13860,63	103,43	99,25
25.8.2020	13649,53	**249,32**	**98,17**
26.8.2020	14661,59	74,45	99,49
27.8.2020	12969,60	168,31	98,70
28.8.2020	12811,58	106,22	99,17
29.8.2020	13317,52	116,76	99,12
30.8.2020	13734,44	195,90	98,57
31.8.2020	16874,87	**375,71**	**97,77**
Average	**14095,11**	**127,11**	**99,1**

Table 2. *Sulfur dioxide concentrations in flue gas before and after treatment and desulfurization efficiency for the month of August 2021*

Date	Emission SO_2 mg/Nm^3		Plant efficiency (%)
	1 – influent	2 – effluent	
1.8.2021	15028,73	151,60	98,99
2.8.2021	16080,59	152,79	99,04
3.8.2021	16873,01	157,08	99,06
4.8.2021	17117,08	159,40	99,06
5.8.2021	15803,92	164,25	99,96
6.8.2021	15657,55	167,77	99,92
7.8.2021	14401,84	142,66	99,00
8.8.2021	16613,23	157,50	99,05
9.8.2021	17805,98	131,60	99,26
10.8.2021	17332,50	140,22	99,19
11.8.2021	15439,75	180,98	98,82
12.8.2021	15932,38	191,00	98,80
13.8.2021	15223,15	194,53	98,72
14.8.2021	15479,57	194,79	98,74
15.8.2021	0	0	0
16.8.2021	0	0	0
17.8.2021	0	0	0
18.8.2021	15108,99	134,02	99,11
19.8.2021	14541,26	138,86	99,04
20.8.2021	14272,83	139,71	99,02
21.8.2021	15696,21	133,64	99,14
22.8.2021	15308,90	142,64	99,06
23.8.2021	15125,80	133,51	99,11
24.8.2021	15632,63	141,43	99,09
25.8.2021	15349,53	137,32	99,10
26.8.2021	15286,59	139,45	99,08
27.8.2021	15280,60	139,31	99,08
28.8.2021	14632,58	140,22	99,04
29.8.2021	0	0	0
30.8.2021	16533,44	134,90	99,18
31.8.2021	15576,87	137,71	99,11
Average	**13649,52**	**131,57**	**99,1**

Table 3. *Sulfur dioxide concentrations in flue gas before and after treatment and desulfurization efficiency for the month of August 2022*

Date	Emission SO_2 mg/Nm^3		Plant efficiency (%)
	1 – influent	2 – effluent	
1.8.2022	11583,73	149,60	98,70
2.8.2022	14809,59	137,79	99,06
3.8.2022	14403,01	144,15	98,99
4.8.2022	12864,08	140,40	98,90
5.8.2022	10719,92	151,25	98,58
6.8.2022	12523,55	137,71	98,90
7.8.2022	13028,84	144,63	98,88
8.8.2022	14641,23	142,50	99,02
9.8.2022	0	0	0
10.8.2022	0	0	0
11.8.2022	0	0	0
12.8.2022	0	0	0
13.8.2022	0	0	0
14.8.2022	0	0	0
15.8.2022	13566,26	142,19	98,95
16.8.2022	13856,35	140,54	98,98

17.8.2022	14724,11	145,11	99,01
18.8.2022	14379,79	144,02	98,99
19.8.2022	14069,69	142,86	98,98
20.8.2022	15193.19	143,71	99,05
21.8.2022	15294,13	140,64	99,08
22.8.2022	15315,12	140,64	99,08
23.8.2022	15225,16	139,51	99,08
24.8.2022	0	0	0
25.8.2022	0	0	**0**
26.8.2022	14815,59	140,45	99,05
27.8.2022	13868,60	142,31	98,97
28.8.2022	15414,58	140,22	99,09
29.8.2022	0	0	0
30.8.2022	0	0	0
31.8.2022	0	0	**0**
Average	**9041,82**	**91,94**	**98,9**

Table 4. *Sulfur dioxide concentrations in flue gas before and after treatment and desulfurization efficiency for the month of August 2023*

Date	Emission SO_2 mg/Nm^3		Plant efficiency (%)
	1 – influent	2 – effluent	
1.8.2023	15524,73	135,60	99,12
2.8.2023	16037,59	137,79	99,14
3.8.2023	15396,01	134,15	99,12
4.8.2023	16136,08	140,40	99,12
5.8.2023	15870,92	142,25	99,10
6.8.2023	16480,55	137,71	99,16
7.8.2023	16252,84	145,63	99,10
8.8.2023	16068,23	137,50	99,14
9.8.2023	14302,21	160,36	98,87
10.8.2023	13294,54	171,25	98,71
11.8.2023	14239,57	157,22	98,89
12.8.2023	0	0	0
13.8.2023	0	0	0
14.8.2023	0	0	0
15.8.2023	14702,26	0	100,00
16.8.2023	15262,35	0	100,00
17.8.2023	15705,11	140,11	99,10
18.8.2023	14658,79	110,02	99,24
19.8.2023	12603,69	150,86	98,80
20.8.2023	13826.19	152,71	99,00
21.8.2023	14987,13	149,64	99,00
22.8.2023	14636,12	142,64	99,02
23.8.2023	14605,16	155,51	98,93
24.8.2023	15048,21	136,22	99,09
25.8.2023	14326,35	162,21	98,86
26.8.2023	14807,59	142,45	99,03
27.8.2023	0	0	0
28.8.2023	0	0	0
29.8.2023	14257,21	129,11	99,09
30.8.2023	13337,35	138,65	98,96
31.8.2023	12807,68	144,64	98,87
Average	**12424,98**	**111,43**	**99,1**

SO_2 concentrations in the flue gas inlet stream in the month of August 2020 ranged from 12811.58 mg/Nm^3 to 14965,73 mg/Nm^3 (table 1), which greatly exceeds the permitted limits, while the output concentrations were in the range of 74.64 mg/Nm^3 to 2091,50 mg/Nm^3, which indicates that the permitted concentration of SO_2 was exceeded in the flue gas output stream as well. During the month of August 2020 (*Table 1*) emission SO_2 exceeded the legally prescribed value of 147 mg/Nm^3 three days (on the 8th, 25th and 31st), was 2091.5 mg/Nm^3, 249.32 mg/Nm^3 and 375,71 mg/Nm^3, respectively. On 8.8.2020, the largest amount of SO_2 was released into the air, which was 2091.50 mg/Nm^3. The failure of the plant to reduce the amount of SO_2 emission is highlighted as the main reason for the release of such a large emission of sulfur dioxide due to system failures and untimely intervention to prevent it. Emission of sulfur dioxide on 25.8.2020 was 249.32 mg/Nm^3. This quantity does not represent a significant exceedance of the permitted concentration of SO_2 because the value is slightly higher compared to the amount of SO_2 emissions allowed by law (200 mg/Nm^3). On the last day of August, the amount of SO_2 emissions at the exit was 375.71 mg/Nm^3, which represents a significant increase in SO_2 emissions, the cause of which is a higher concentration of SO_2 at the very entrance, and because of this the FGD plant failed to sufficiently reduce emissions at the exit even if the efficiency was still high (efficiency 97.78%). Although daily concentrations in the month of August 2020 exceeded the permitted concentration in three cases (August 8, 25 and 31), this was not the case in 2021, 2022 and 2023.

The first real monthly results were recorded yet in August 2021, because the desulfurization plant only then started stable and continuous operation, which is a prerequisite for relevant emission measurements, and then the average value of SO_2 was

Table 5. *Data on average emissions of O_2, SO_2, NO_x and dust measured in August 2020*

Measured place	Year	Month	O_2 (mg/Nm^3)	SO_2 (mg/Nm^3)	NO_x (mg/Nm^3)	Dust (mg/Nm^3)
1 - influent	2020	August	9,01	14095,11	369,8	127,89
2 - effluent	2020	August	8,71	127,11	335,96	1,56
Efficiency (%)	-	-	-	99,098	9,15	98,78

131.57 mg/Nm^3 (Table 2), which is within the limits of the permitted emission. Also, the data from 2022 and 2023 show that the average values of SO_2 emissions in August amounted to 91.94 mg/Nm^3 (Table 3.) and 111,41 mg/Nm^3 (Table 4), respectively.

Based on the available data, it was observed that the average amount of SO_2 emissions at the exit in no case did it exceed the limit value allowed by law.

Table 5 shows data on average input and output amounts of SO_2 emissions, NO_x, O_2 and solid particles, measured in August 2020. The data presented in table 5 refer to the first preliminary measurement of SO_2 emission values in August 2020 and they show that a desulfurization efficiency of 99% was achieved.

Based on the data shown in the Table *5* a large difference is observed in the average inlet and outlet concentrations of sulfur dioxide. Average inlet concentration of SO_2 during the month of August 2020 was 14095.11 mg/Nm^3, which is many times higher than the legally prescribed value of 200 mg/Nm^3. After passing the flue gas through the FGD plant, the concentration of SO_2 was significantly reduced and its average value in August 2020 was 127.11 mg/Nm^3.

Considering the achieved average values of SO_2 concentration in the input and output flow of flue gas for the month of August 2020, it can be seen that the efficiency of the flue gas desulfurization plant at the Ugljevik Thermal Power Plant for the month of August 2020 was 99.098%.

The achieved desulfurization efficiencies per month on an annual basis ranged from 83.91 to 91.42% for 2020, from 98.72% to 99.96% for 2021, from 98.58% to 99.09% for 2022, and from 98.80% to 100% for 2023.

The maximum efficiencies achieved in 2020, 2021, 2022 and 2023 were 99.42%, 99.96%, 99.09% and 100%, respectively.

Based on the data shown in the Table *5,* it is observed that the emission of SO_2 at the exit is significantly reduced compared to the input quantities of sulfur dioxide emissions.

Average, maximum and minimum concentrations of SO_2 emissions from the desulphurization plant of the Ugljevik Thermal Power Plant, for selected months in the period 2020-2023, are shown in table 6. Based on the data presented, it can be seen that the maximum allowed concentration of SO_2 was exceeded in the emitted flue gas.

Taking into account the relevant data from the permits for electricity production issued by the regulatory commissions from the Federation of Bosnia and Herzegovina (FBiH) and the Republic of Srpska (RS), as well as data obtained directly from the

Table 6. *Presentation of the average, maximum and minimum measured value of* SO_2 *emissions for selected months from 2020 to 2023.*

Year	Month	Average SO_2 mg/Nm^3	Max SO_2 mg/Nm^3	Min SO_2 mg/Nm^3
2020	July (26.-31.7.)	132,56	17 9,56	74,83
2021	August	127,11	180,00	76,50
2022	February	**232,25**	319,38	178,63
2022	April	**216,33**	300,66	160,66
2023	January	**279,00**	399,33	196,67

Legend: Y-year of emissions measurement; m-month of emissions measurement; p-average of the measured emission; max-maximum measured emission value; min-minimum measured emission value;

operators of large combustion plants, a total of 12 large combustion plants (LCP) has been identified in BiH, among which there are 10 large thermal power plants. The Ugljevik Thermal Power Plant is recognized as a large combustion plant in the Republic of Srpska, together with the Gacko Thermal Power Plant. Based on the methodology from *Policy Guidance for the Establishment of National Emissions Reduction Plans* published by the Secretariat of the Energy Community [9], as well as data from *the National Emissions Reduction Plan for Large Combustion Plants of Bosnia and Herzegovina* [10], limit values of sulfur dioxide emissions were calculated for the identified plants for the period 2016–2027. Limit values were determined based on the average fuel consumption in the period 2008-2012, in accordance with the methodology prescribed in the mentioned documents.

Based on the data for limit values of sulfur dioxide emissions (SO_2) for large combustion plants (LCP) on an annual basis, in the period from 2018 to 2027, there is a clear trend of gradual reduction of the permitted amounts of discharge of this polluting gas from year to year.

The total amount of SO_2 emissions for all plants in Bosnia and Herzegovina is 27,194 t per year in the period from 2018 to 2023. After that, the values progressively decrease to 22,877 t (2024), 18,560 t (2025) and finally to 14,243 t in 2026 and 2027. This pattern reflects efforts to reduce SO_2 emissions to a minimum, that is, to control and reduce sulfur dioxide emissions, which can have a positive impact on air quality and the health of the population, especially in industrial regions. Viewed individually, the thermal power plants of the Federation of BiH and the Republic of Srpska show a similar trend of reduction.

5. CONCLUSION

The Thermal Power Plant Ugljevik uses brown coal with a very high sulfur content (5-6%) as the main fuel. Due to the extremely high SO_2 content in brown coal, the only effective way to reduce SO_2 emissions was the construction of a flue gas desulfurization plant. For this purpose, a flue gas desulphurization plant was built in the Ugljevik Thermal Power Plant, the operation of which is based on the principle of the wet limestone process. The FGD plant at the Ugljevik Thermal Power Plant was put into operation in 2020 and has been operating with occasional interruptions since then. After the introduction of the wet limestone desulfurization process, a significant reduction in sulfur dioxide emissions was achieved, which significantly improved the efficiency of the system. The efficiency of desulfurization is over 95%, which enables compliance with environmental standards and regulations related to the emission of harmful gases.

Reduction of SO_2 concentration in flue gases has multiple benefits. It primarily contributes to the improvement of air quality in the vicinity of the thermal power plant, thereby reducing the risk of respiratory diseases among the population. The occurrence of acid rain, which negatively affects the soil, water ecosystems and vegetation, is reduced. Also, the construction of a flue gas desulfurization plant enabled the thermal power plant to continue operating in accordance with environmental standards, thereby avoiding potential sanctions and restrictions on electricity production.

It can be said that the construction of the FGD facility at the Ugljevik Thermal Power Plant was a necessary step towards reducing the negative impacts of the thermal power plant on the environment. The achieved efficiency of the system proves that the applied technology is successful in controlling sulfur dioxide emissions, which contributes to a more sustainable and environmentally friendly operation of the thermal power plant.

6. LITERATURE

[1] Air Quality Management . (2019). Air Pollution Management in Bosnia and Herzegovina. Air Quality Management in Bosnia and Herzegovina.

[2] Đukić, V., Kulanić, D., and Đukić, O. (2018). The Impact of Air Pollution on the Health of the Population in the City of Tuzla. *Sports Sciences and health, 8,* 119-126.

[3] Despotović, Ž. (2020). *Desulfurization of Flue Gases in Industry.* Belgrade: High School of Electrical Engineering and Computing of Vocational Studies, Viser.

[4] Jovanović V, Jovanović M, Flue Gases Desulfuration In Serbia - Technological Procedures, Legal And Economic Aspects (2020)

[5] Zhang, Y., Wang, Q., & Liu, H. (2018). *Study on the Efficiency of Flue Gas Desulfurization Systems*. Journal of Environmental Engineering, 144(3), 123-135.

[6] Aleksandar Jovović, Dragoslava Stojiljković, Dejan Radić, Dušan Todorović, Marko Obradović, Vladimir Jovanović, Nenad Manić, Đorđina Milovanović (2012) Flue Gas Desulfurization in Lignite Coal-fired Thermal Power Plants - Analysis of Influencing Parameters and Choice of Technical Solution.

[7] Gvozdenović, J., Ilić, N., & Petrović, B. (2021). *Technology for Reducing Sulfur Dioxide Emissions from Thermal Power Plants*. Energy Institute, Belgrade.

[8] IBM Corp. (2011). IBM SPSS Statistics for Windows, version 20.0. Armonk, NY: IBM Corp.

[9] Energy Community Secretariat. (2013). *Policy Guidelines for the Establishment of National Emissions Reduction Plans*. Belgrade, : Energy Community Secretariat.

[10] Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina. (2015). *National Emission Reduction Plan for Large Combustion Plants of Bosnia and Herzegovina*. Sarajevo: Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina.

АНАЛИЗА ЕФИКАСНОСТИ ПРОЦЕСА ОДСУМПОРИЗАЦИЈЕ ДИМНИХ ГАСОВА У РУДНИКУ И ТЕРМОЕЛЕКТРАНИ УГЉЕВИК

Сажетак: Димни гасови из термоелектрана на угаљ садрже гасове (углавном SO_2, NO_x, CO, CO_2) и фине честице летећег пепела. Концентрација оксида сумпора у димном гасу зависи од количине сумпора у угљу који сагоријева. У процесу одсумпоравања димних гасова из Рудника и Термоелектране Угљевик примјењује се мокри скруберски поступак, који користи суспензију кречњака као средство за апсорпцију оксида сумпора, при чему се као нуспродукт производи гипс. Анализиране вриједности емисије прије и након пуштања у рад постројења за ОДГ показују да је примјењена технологија за ОДГ у РиТЕ Угљевик изузетно ефикасна. Ефикасност постројења за одсумпоравање се кретала у распону од 83,91 до 100%, у зависности од улазне концентрације SO_2 у димном гасу. Процјене показују да постројење за ОДГ, у зависности од интензитета рада, може годишње издвојити од 7.000 до 55.800 тона сумпора, уз производњу 3.660 до 29.280 тона гипса. Увођење овог поступка пречићавања димних гасова значајно смањује оптерећење животне средине и амбијенталног ваздуха оксидима сумпора. Нажалост, из економских разлога постројење не ради континуирано.

Кључне ријечи: Димни гасови, емисија SO_2, одсумпоравање, мокри скруберски поступак.

Paper received: 21 August 2025 **Paper accepted: 31 March 2026**

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License