ANALYSIS AND COMPARISON OF MEASUREMENTS OF EMISSION OF HARMFUL POLLUTANTS SO_2, NO_X AND DUST BETWEEN THE TE (THERMAL POWER PLANT) BITOLA, MACEDONIA AND POWER PLANTS IN THE SAME LIGNITE BASIN IN GREECE

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ABSTRACT: The emissions of SO_2, NO_X and dust primarily affect local air quality, but also contribute to pollution from a regional perspective i.e. to the trans-boundary pollution, causing damage to human health and the environment. The thermal power plants are a major source of these pollutants including suspended particulate matters PM, which are emitted into the air as primary and secondary with reactions of SO_2, NO_X into the atmosphere. Therefore continuous monitoring and analysis of these pollutants is of great importance in efforts to reduce them.

The content in this paper includes data analysis of the measured emission values of C from the Thermal power plant REK Bitola and the Thermal power plants in Northern Greece from 2007 to 2012. The data on measured values from emissions of SO_2, NO_X and dust from the Thermal power plant REK Bitola are taken from the annual reports of ELEM while data on emissions of SO_2, NO_X and dust from the Thermal power plants in Northern Greece are taken from EEA-*European Pollutant Release and Transfer Register (E-PRTR).*

Data processing has been performed, and also the emission of pollutants are displayed tabular and graphic for each separately in order to determine the conditions of emissions of SO_2, NO_X and dust in the specified period and to see if emissions are improved compared to the past. Also a comparison of emissions from the Thermal power plant REK Bitola and the Thermal power plants in Northern Greece has been made, in order to determine the impact of emissions from this region. The analysis and conclusions arising from the processed data are an integral part of this paper.

Keywords: Thermal power plants, pollutants, SO_2, NO_X, dust

INTRODUCTION

Air pollution is a very important element for the environment and at the same time is a complex problem with a great challenge to its reduction and managing. Air quality continues to be an important issue that is related to public health, economy and environment.

The problems of air pollution already exceed local importance and is an issue that is discussed in a wider regional context. Air pollution can be created and transported over long distances and can affect a large area. The transport of pollutants i.e. the cross-border pollution caused by atmospheric movements represents a huge challenge for the region. Air pollution leads to negative effects on regional level and there are several significant environmental impacts and can directly affect vegetation, water quality and soil.

Particulate matter (PM), are formed as primary directly emitted in the atmosphere and secondary which are formed in the atmosphere. Main precursor gases, responsible for forming

secondary PM are: SO2, NO_X, NH_3, and VOC (chemical compounds whose molecules contain carbon). The main precursor gases react in the atmosphere and form compounds of sulphates, nitrates and ammonia. These compounds form new particles in the air or react with other particles and form so-called inorganic aerosols.

Samples of air particulate matter in urban areas around the world usually indicate mainly on the same components in significantly different proportions according to the location of sampling.

1. EMISSIONS OF SO_2, NO_X, AND DUST FROM THE THERMOELECTRIC POWER PLANT "REK BITOLA"

The Thermoelectric power plant REK Bitola is located in the southern part of the Republic of Macedonia in the Pelagonia region, at a distance of 12 km from the city of Bitola. The thermoelectric power plant is consisted of three blocks. The first was established in 1982, the second was put in use in 1984 and the third in 1988. The total capacity of the thermoelectric power plant is 675 MW.

As a result of the manufacturing process, the thermoelectric plant discharges emissions of harmful air pollutants that are constantly monitored. In Table 1 and Chart 1 are presented emissions of SO_2, NO_X and dust from the thermoelectric power plant REK Bitola in the period from 2004 to 2012 in tonnes per year. Data on emissions' discharges are taken from the annual reports of ELEM.

Year	SO_2 t/yearly	NO_X t/ yearly	dust t/ yearly
2012	66891,81	16643,33	9256,92
2010	60443,29	17370,56	6605,48
2009	75044,99	16768,00	6673,00
2008	49094,00	14140,00	6673,00
2007	49415,00	8929,00	8454,00
2006	49561,00	9680,00	3397,00
2005	30387,00	8503,00	2245,00
2004	28720,00	8057,00	2127,00

Table 1: Concentrations of SO_2 , NO_X and dust from REK BITOLA in tonnes yearly, Source: Annual reports from ELEM

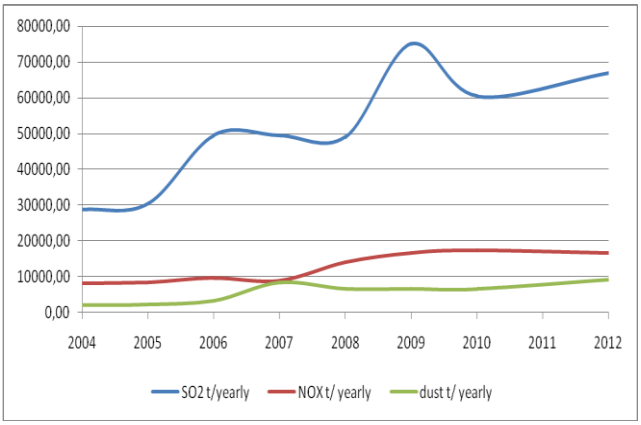

Chart 1 : Chart of emissions of SO_2 , NO_X and dust from REK BITOLA in tonnes yearly

From the chart, it can be concluded that the dust emissions in 2012 amounts 9256.92 tonnes per year and they are more than four times higher, compared to 2004 when they amounted to 2127 tonnes per year. The recorded dust emissions are significantly bigger in 2007 and it is constantly kept up to 2012.

Emissions of nitrogen oxides that amounted 8057 tonnes annually in 2004 - rose and in 2012 they amounted 16,643.33 tonnes annually, which is twice as much. Emissions of nitrogen oxides increased dramatically in 2008 and since then until 2012 continuously grew shown on Chart 1.

From the chart we can notice that the emissions of sulphur dioxide has dramatically increased in the period from 2006. The highest concentration was observed in 2009 with 75,044.99 tonnes per year, which is twice and a half times higher than emissions in 2004 which are amounted to 28720 tonnes annually. In 2010 there is decrease of emissions of sulphur dioxide - 60,443.29 tonnes per year and from then until 2012 there is a continuous increase in emissions that are more than two times higher than in 2004.

From the chart we can conclude that emissions of sulphur dioxide have increased dramatically in 2006, dust emissions drastically increased in 2007 and nitrogen oxide emissions drastically

increased in 2008. Emissions of nitrogen oxides and sulphur dioxide doubled between 2004 to 2012 and dust emissions have increased by more than four times in the same period.

For calculating the emission from kg/h in mg/m3 the following equation is used

$$E = C \cdot Q \cdot 0.0036$$

where:
E- emission of the substance in kg/h
C - concentration of the pollutant in mg / m^3
Q - volumetric flow of gas in m^3/s
0.0036 - factor of converting the mg/s in kg / h
Q = 3900987 m_3 / h, for REK BITOLA, Source: **the thermal power plant REK BITOLA, BERCEN Training Program on On-site Inspection For the Environmental Enforcement Agencies and Inspectorates, September 9-12, 2003**

Year	SO2 kg/h	SO2 mg/m^3	NOX kg/h	NOx mg/m^3	Dust kg/h	Dust mg/m^3
2012	7636	1957,48	1890	487,04	1057	270,89
2010	6900	1768,77	1983	508,32	755	193,30
2009	8567	2196,07	1914	490,69	761	195,27
2008	5604	1436,66	1614	413,78	762	195,27
2007	5641	1446,05	1019	261,29	965	247,39
2006	5658	1450,32	1105	283,27	388	99,41
2005	3469	889,23	971	248,83	256	65,70
2004	3279	840,44	920	235,78	243	62,24

Table 2: Concentrations of SO_2, NO_X and dust from REK BITOLA in kg/h and mg/m^3 , Source: Annual reports in ELEM

Chart 2: Concentrations of SO_2 , NO_X and dust from REK BITOLA in kg/h and mg/m^3 , Source: Annual reports in ELEM

The values of certain pollutants shown in Chart 2 are taken from the EU Directive on limitation of emissions of certain pollutants into the air from large combustion plants 2001/80 / EC. We can notice from the chart that emissions of sulphur dioxide from 2004 to 2012 consistently exceeded the limit values. The greatest overcoming is achieved in 2012 when emissions of sulphur dioxide from REK BITOLA had exceeded limit values by ten times.

Nitrogen oxide's emissions are within the permitted limits since 2009, although earlier in the period from 2004 to 2008 they were almost twice lower than the limit values.

Emissions of dust is within the range of 2004 to 2006 and in 2007 it exceeded the limit values by two and a half times. Such high dust emissions are continuously emitted into the air until 2012.

2. SO_2 EMISSIONS FROM THE THERMAL POWER PLANT "REK BITOLA" AND THE THERMAL POWER PLANT IN NORTHERN GREECE

To determine the impact and to compare emissions from the thermo-electrical plants installed in Northern Greece to the border with Macedonia, the following thermal power plants are taken for analysis: Meliti, thermal power plant located near Florina with capacity of 330 MW, Agios Dimitrios located at 13 km from Kozani with capacity of 1500 MW, Kardia located at 12 km from Kozani with capacity of 1200 MW, Amindeo located 9 km from Amindeo with capacity of 600 MW, Ptolemaida, located near Ptolemaida with a capacity of 495 MW.

Table 3 shows SO_2 emissions from the thermal power plants REK BITOLA, MELITI, PTOLEMAIDA, KARDIA, AMINDEO and AGIOS DYMITRIOS in the period from 2007 to 2012 in tonnes per year. The data are taken from the annual reports of ELEM and annual reports EEA- *European Pollutant Release and Transfer Register (E-PRTR).*

THERMO POWER PLANT	CAPACITY MW	2012	2010	2009	2008	2007
REK BITOLA	675	66892	60443	75045	49094	49415
MELITI	330	710	2060	2240	2510	2610
AGIOS DYMITRIOS	1500	28900	46400	58000	48000	41400
AMINDEO	600	20000	37900	20200	30600	22700
PTOLEMAIDA	495	8300	4900	6670	3470	4980
KARDIA	1200	10900	6000	9280	7110	3180

Table 2: Sulphur dioxide emissions (SO_2) from the thermo power plants in the region in tonnes/per year, Source: Annual reports of ELEM, EEA- *European Pollutant Release and Transfer Register (E-PRTR)*

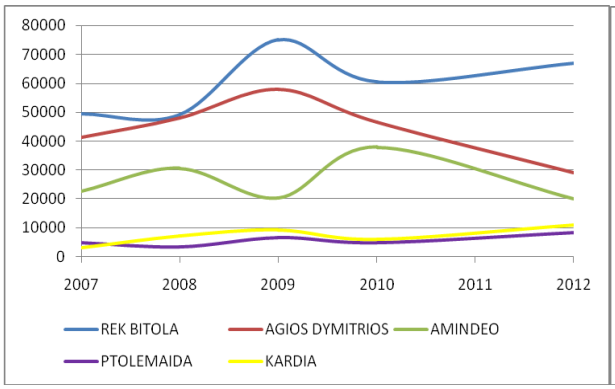

Chart 2: The SO_2 emissions from REK BITOLA, PTOLEMAIDA, AMINDEO, AGIOS DYMITRIOS and KARDIA in tonnes a year

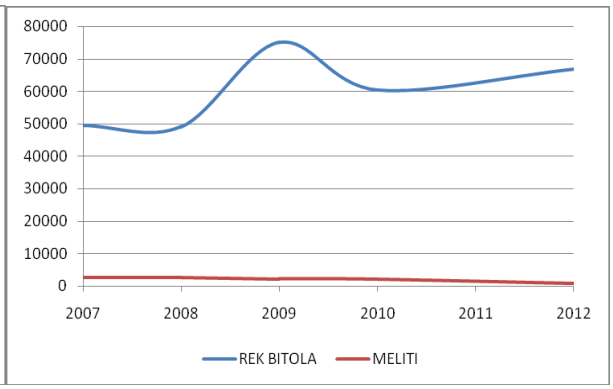

Chart 3: The SO_2 emissions from REK BITOLA and MELITI in tonnes a year.

Chart 2 shows the SO_2 emissions from REK BITOLA, PTOLEMAIDA, KARDIA, AMINDEO and AGIOS DYMITRIOS expressed in tonnes per year where it is evident that emissions from REK Bitola are significantly higher compared to others. The difference is especially expressed for the year 2012.

Meliti is a thermal power plant which is in the immediate vicinity of REK BITOLA and has capacity of approximately twice smaller than REK BITOLA. The SO_2 emissions of this plant in the period from 2007 to 2012 marked a declining trend, and are the lowest of all power plants in northern Greece, and in the year 2012 they were 710 tonnes/annually, which represents about 1% of the emissions that REK Bitola discharged in the same period which amounted of 66.892 tonnes/annually. This was due to modern technical solutions for purification of flue gases implemented at this power plant. The largest polluter in terms of SO_2 in North Greece is the thermal power plant Agios Dimitrios with the highest concentration of SO_2 emissions of 58.000 tonnes/annually in 2009. From that period to 2012 the emissions marked a declining trend, and in the same year amounted 28.900 tonnes and are about two and a half times smaller than REK BITOLA.

To determine the impact of emissions of sulphur dioxide from the power plants in Northern Greece, a comparison has been made of the emissions of sulphur dioxide from Northern Greece and REK BITOLA. In Table 3 are displayed the SO_2 emissions from the thermal power plant REK BITOLA, and the power plants in Northern Greece in the period from 2007 to 2012 expressed in tonnes per year.

THERMAL POWER PLANT	2012	2010	2009	2008	2007
REK BITOLA	66892	60443	75045	49094	49415
NORTHERN GREECE	68810	97260	96390	91690	74870

Table 3: SO_2 emissions from the thermal power plant REK BITOLA and the thermal power plants in Northern Greece in the period from 2007 to 2012 expressed in tonnes/annually, Source: Annual reports of ELEM, EEA- *European Pollutant Release and Transfer Register (E-PRTR)*

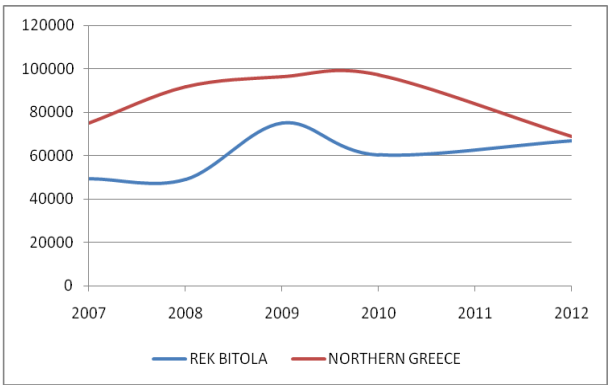

Chart 4: SO_2 emissions from the thermal power plant REK BITOLA and the thermal power plants in Northern Greece in the period from 2007 to 2012 in tonnes/annually

From the Chart 4 we can conclude that the SO_2 emissions from REK BITOLA for the entire period from 2007 to 2012 have increasment, while emissions from the thermal power plants from 2010 have a declining trend and in 2012 they are approximately equal to the value of emissions from REK BITOLA. It is important to note that in Chart 4 the emissions from the thermal power plants in Northern Greece are given cumulative for all power plants with installed electrical capacity of 4125 MW, versus emissions from REK BITOLA with installed power capacity of 675 MW.

3. EMISSIONS OF NO_X FROM THE THERMAL POWER PLANT REK BITOLA AND THE THERMAL POWER PLANTS FROM NORTHERN GREECE

In Table 4 are displayed the NO_X emissions from thermal power plants REK BITOLA, MELITI, PTOLEMAIDA, KARDIA, AMINDEO and AGIOS DIMITRIOS in the period from 2007 to 2012 in tonnes/annually.

THE THERMAL POWER PLANT	2012	2010	2009	2008	2007
REK BITOLA	16643	17371	16768	14140	8929
MELITI	941	1200	1420	1470	1750
AGIOS DIMITRIOS	17700	20300	24800	22600	24300
AMINDEO	3240	4440	4270	10900	8030
PTOLEMAIS	2430	3900	6260	6940	6000
KARDIA	11500	13000	17400	17400	17400

Table 4: Nitro oxide's emissions (NO_X) from the Thermal power plant in the region expressed in tonnes/annually Source: Annual reports of ELEM, EEA- *European Pollutant Release and Transfer Register (E-PRTR)*

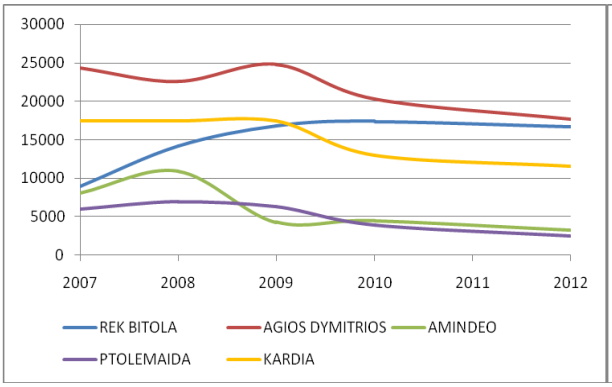

Chart 5:Nitro oxide's emissions (NO_X) from the REK BITOLA, AMINDEO, KARDIA, AGIOS DIMITRIOS and PTOLEMAIDA in tonnes/annually

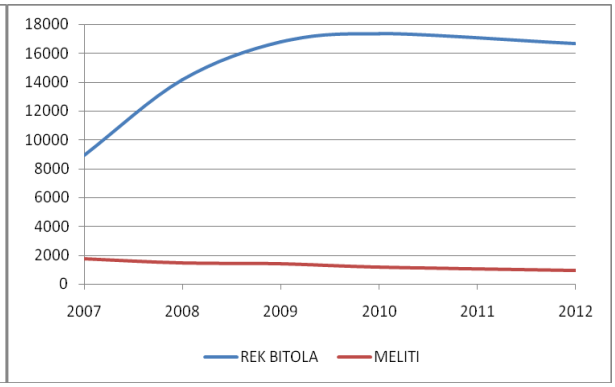

Chart 6: Nitro oxide's emissions (NO_X) from the REK BITOLA and MELITI, expressed in tonnes/annually

From the Chart 5 we can note that the NO_X emissions in REK Bitola dramatically rose in 2008 and that this continuous increase lasted until 2012, where NO_X emissions amounted to 16,643 tonnes per year. In 2007 REK BITOLA had twice lower emissions than KARDIA and three times lower emissions than AGIOS DIMITRIOS, thermal power plants that are ranked among the thirty largest polluters in Europe. But in these power plants we noticed a continuous reduction of emissions and in 2012 of NO_X emissions from Agios Dimitrios and REK BITOLA are almost equal and the emissions from KARDIA are lower than the emissions of REK BITOLA. The remaining thermal power plants have relatively lower emissions than REK BITOLA especially in 2012.

A comparison is made in Chart 6 of emissions of the thermal power plant REK BITOLA and MELITI which is in the immediate vicinity and we can notice that the power plant MELITI from 2007 to 2012 has continuously reduction of nitrogen oxides emissions. The emissions that REK BITOLA has released in 2012 are 17 times higher than those of the thermal power plant MELITI in the same year.

To determine the impact of nitrogen oxides emissions from Northern Greece, a comparison has been made of NO_X emissions from REK BITOLA and Northern Greece. The values of NO_X emissions expressed in tonnes per year, are presented in Table 5:

THERMAL POWER PLANT	2012	2010	2009	2008	2007
REK BITOLA	16643	17371	16768	14140	8929
NORTHERN GREECE	35811	42840	54150	59310	57480

Table 5: Emissions of nitrogen oxides from REK BITOLA and Northern Greece in the period of 2007 - 2012 expressed in tonnes/annually, Source: Annual reports from ELEM, EEA - *European Pollutant Release and Transfer Register (E-PRTR)*

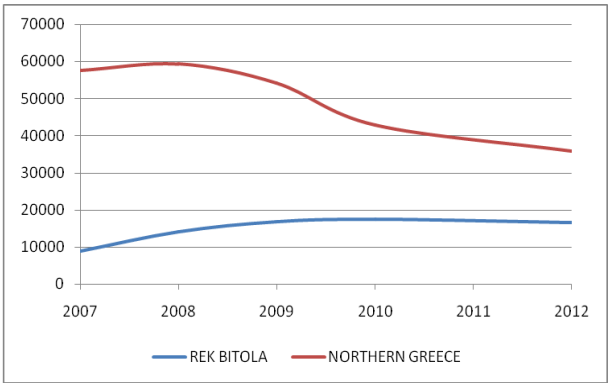

Chart 7: Emissions of nitrogen oxides from REK BITOLA and the thermal power plants in Northern Greece in the period of 2007 - 2012 in tonnes/annually

From the Chart 7 we can note that in 2007 the thermal power plants of Northern Greece had six times higher NO_X emissions than the power plant REK BITOLA. But from that time until 2012 the thermal power plants in Northern Greece have significantly reduced the emissions while the thermal power plant REK BITOLA has marked continuous increase in emissions, and that difference was reduced and in 2012 the emissions that were discharged by the thermal power plants in Northern Greece are twice higher than the emissions of REK BITOLA.

4. EMISSIONS OF DUST FROM THE THERMAL POWER PLANTS IN REK BITOLA AND THE POWER PLANTS FROM NORTHERN GREECE, AGIOS DIMITRIOS, PTOLEMAIDA AND KARDIA

Table 6 shows the measured values of dust emissions from the thermal power plant REK BITOLA and from the thermal power plants Agios Dimitrios, Ptolemaida and Kardia located in Northern Greece expressed in tonnes per year.

THERMAL POWER PLANT	2012	2010	2009	2008	2007	2006	2005	2004
REK BITOLA	9257	6605	6673	6673	8454	3397	2245	2127
AGIOS DIMITRIOS	730	861	588	711	6160	10020	15390	26510
PTOLEMAIDA	7048	6803	6316	8969	12460	3350	3410	5410
KARDIA	3077	2407	2457	4492	3270	5960	4910	2050

Table 5: DUST emissions from the thermal power plant REK BITOLA and from the thermal power plants in Northern Greece in the period 2004-2012 expressed in tonnes per year, Source: Annual reports from ELEM, EEA - *European Pollutant Release and Transfer Register (E-PRTR)*

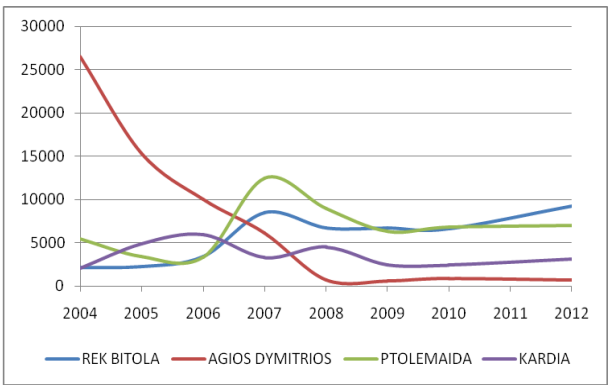

Chart 8: DUST emissions from the thermal power plant REK BITOLA and from the thermal power plants in Northern Greece - Agios Dimitrios, Ptolemaida and Kardia in the period 2004-2012 expressed in tonnes per year

From the Chart 8 we can note that in 2004 REK BITOLA had significantly lower dust emissions compared to Agios Dimitrios and Ptolemaida and almost identical with KARDIA. Dust emissions that REK BITOLA emitted in 2004 amounted to 2127 tonnes per year. From that period until 2012 emissions increased by four times in 2012 and amounted to 9257 tonnes per year and more than twelve times higher than the Agios Dimitrios and three times more than the Kardia.

5. CONCLUSIONS

From the performed analysis and comparison of data on emissions of harmful substances from the operation of the thermal power plant REK BITOLA in the Republic of Macedonia and the five thermal power plants in Northern Greece (Meliti, Kardia, Agios Dimitrios, Ptolemaida and Amindeo), we can conclude the following:

- Emissions of sulphur dioxide from REK BITOLA in 2012 are 2.33 times higher than the emissions in 2004
- Emissions of nitrogen oxides from REK BITOLA in 2012 is 2.06 times higher than emissions in 2004
- Emissions of dust from REK BITOLA in 2012 to 4.35 times higher than emissions in 2004
- Emissions of sulphur dioxide from REK BITOLA with capacity 675 MW in 2012 are 2.86% lower than the cumulative emissions of the thermal power plants in Northern Greece with total capacity of 4125 MW
- Emissions of nitrogen oxides from REK BITOLA with a capacity of 675 MW in 2012 to 53.5% are lower than emissions of power plants in northern Greece with a total capacity of 4125 MW.

Except in the thermal power plant Meliti which is equipped with modern equipment for purification of flue gases (water scrubber for desulfurization of flue gases), among the other reviewed thermoelectric plants, other than an electrostatic filter for removal of the dust (ash) from the flue gases, there is no processing equipment (purification) of flue gases before their discharge in the atmosphere.

REFERENCE

1. DIRECTIVE 2001/80/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the limitation of emissions of certain pollutants into the air from large combustion plants, 2001

2. The thermal power plant REK BITOLA, BERCEN Training Program on On-site Inspection For the Environmental Enforcement Agencies and Inspectorates, September 9-12, 2003
3. Annual reports from ELEM
4. EEA- *European Pollutant Release and Transfer Register (E-PRTR)*
5. Reducing air pollution from electricity-generating large combustion plants in the European Union , An assessment of potential emission reductions of NO_X, SO_2 and dust, EEA Technical report No 9/2013