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THE IMPACT OF COAL PROCESSING TECHNOLOGY ON THE ENVIRONMENT

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Abstract. *Major presence of different types of coal in the production of electric and thermal energy indicates the need to use them. On the other hand they are the main factor in the pollution of the environment. Thus we create an absurd situation in which the process and the use of coal with the purpose to enable better life and higher standards of men lead to the degradation of basic living conditions.*
This paper will present the impact of coal processing technology in thermal plants on the quality of the environment. The purpose of this paper is to motivate the use of economically and technologically justified technologies in coal exploatation. In this way energy efficiency is increased, which leads to the reduction of energy use and financial savings, and eventually to the increase in the quality of the environment.

Key Words: *coal, the environment, energy efficiency.*

INTRODUCTION

Coal is a sediment rock which can be made of the remains of land and not very often water plants and a variable quantity of non-organic materials (less than 50%). It was found on every continent on different depths in sediments of different geological periods, from the paleozoic to kenozoic [1]. Its importance for mankind is immense.

Total use of the available coal resources is possible though the use of different methods of its processing. The following processes in coal research have been particurlarly empasised lately: extraction, hydrogenization, halogenization, hydrolysis, oxydation and neutralization. Through the use of different technological processes coal has found its application in the production of numerous new products (coke, generator gas, tar, humic fertilizers etc.) [2]. However, the use of coal in the production of heat and electric enegy has played a dominant part in its use so far. The results of the geological research show

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that significant quantities of different types of coal can be found on every continent (Table 1).

Table 1. Coal reserves in the world

	Coals reserves ($\times 10^9$ t)
Eastern Europe & FSU	135.4
North America	11.9
The rest of Asia	70.7
China	62.2
Africa	61
Australia	45.3
Western Europe	27.6
South & Central America	5.6

The burning of coal in power plants emits large quantities of harmful substancies that influence air, water and land pollution. Green house effect is the consequence of the emission of large quantities of carbon-dioxide, which contributes to the global warming.

Nowadays new ways and processes to increase the efficiency of coal conversion, protect the environment and make production more efficient are being looked into. This can be achieved through the introduction of pure contemporary technologies in coal burning as well as through the improvement of classic technology. Therefore, this paper analyses the impact of coal processing technology and its application in thermal power plants on the environment in the Republic of Serbia.

1. COAL EXPLOITATION

Depending on whether coal can be found on the surface or somewhere under ground, coal is exploited by underground, surface or underwater exploitation. Geological research shows that the Republic of Serbia has significant coal resources. Their quantity and categories are given in Table 2 and show that total geological resources af all coal types in the Republic of Serbia come up to 20.1 billion tones, 16.7 billion tones being balance and 3.4 billion tones non-balance resources. The dominance of lignite is obvious [3].

Table 2. Total geological resources of coal in the Republic of Serbia

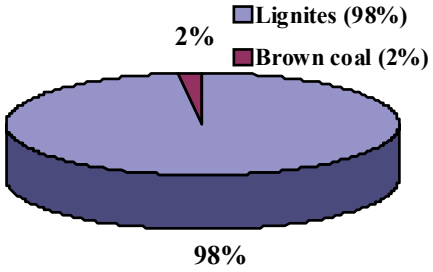
Coal type	Geological resources ($\times 10^3$ t)	
	Being balance	Non-balance
Stone coal	6.174	
Brown coal	90.120	
Brownlignites	277.068	
Lignites	16.339.136	3.409.805
In total	16.712.948	3.409.805

According to the data from the Resource Balance, more than 76% of total coal resources in the Republic of Serbia are located in the basin of Kosovo and Metohia, 14 % in the basin of Kolubara, 3.3% in the basin of Kostolac and 2.7% in the basin of Sjenica and Kovin. In the structure of balance resources 93% is lignite. Total coal production in the Republic of Serbia (without the basin of Kosovo and Metohia) was in constant rise in the period between 2001 and 2009 (table 3) [4].

Table 3. Coal production in the Republic of Serbia in the peroid between 2001 and 2009 (without Kosovo and Metohia)

Year	Coal production ($\times 10^6$ t)
2001	30.49
2003	32.81
2005	34.46
2007	36.51
2009	37.78

The greatest part of the domestic coal production goes to the production of low calory lignite found in surface exploitation (the mines of Kolubara and Kostolac). Picture 1 shows coal structure in total domestic production in 2008 [5].



Picture 1. The structure of coal production in the Republic of Serbia in 2008

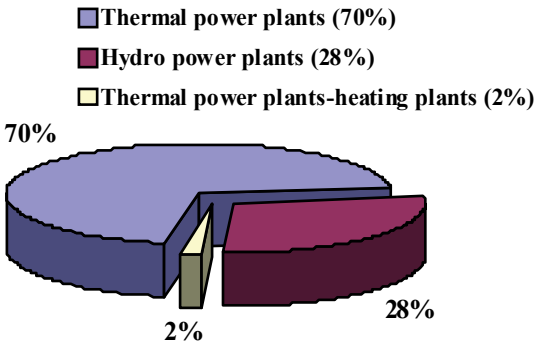
2. COAL PROCESSING IN THERMAL POWER PLANTS

Most thermal power plants in the world use stone coal, brown coal, lignite, oil derivatives, natural and coke gas, even wood. A thermal power plant of 1000 MW uses about 2.5 million tones of stone coal a year. On the other hand, thermal power plant Nikola Tesla in Obrenovac uses about 900 t/h of lignite in one kettle. Coal is grinded into fine dust in special mills and then blown into the kettle by hot air [6].

The Europen Union has set as its goal to reduce the emission of CO_2 by at least 20% by 2010. A particurlar empasise is put on the introduction of new technologies in thermal power plants which use coal. The latest solutions include modern accumulation plants which achieve an efficiency of 70% in combination with gas turbines. They emit 3% less CO_2 per kilowatt of electric energy than the present combined cyclic plants. Through the use of the new gas turbines, 60% efficiency in the combined cyclic plants is expected to

be achieved. New plants will emit 2.8 million tones of CO_2 less than the conventional plants which operate on the principle of coal combustion [7]. If all coal operated plants used the latest technology, the emission of CO_2 would be reduced by 25% and about 2 billion tones of CO_2 less would be emitted worldwide.

The production of electric energy in the Republic of Serbial is mostly done within JP Elektroprivreda Srbije and the share of plants in the production of electric energy in the Republic of Serbia is given in Picture 2.



Picture 2. The structure of plants in the Republic of Serbia

Thermal energy capacities in the Republic of Serbia are:

a) eight thermal power plants with 25 blocks which use lignite of 5.171 MW net installed power, two of which are thermal power plants with seven blocks of 1.235 MW net installed power on the territory of Kosovo and Metohia and

b) three thermal power plants – hetaing plants with 6 blocks of total 353 MW net power, which use liquid and gas fuel [8].

The current status of temporary management on the territory of Kosovo and Metohia is regulated by Resolution 1244 of the UN Safety Council from 1999 and it does not enable Elektroprivreda Srbije to use and manage electro-energetic resources in Kosovo and Metohia as integral parts of its system.

Thermal power plant Nikola Tesla A in Obrenovac is the biggest plant in Serbia and on the Balkan peninsula with six blocks of 1.650 MW total power (two blocks of 210 MW and four blocks of 308 MW). It is situated on the left bank of the river Sava, 30 kilometers upstream of Belgrade. It is also the biggest separate producer of electric power in the electro-energetic system of Serbia, with 8 billion kilowatt-hours a year. Through long distance thermal pipeline this plant also delivers heat for central heating to residential and business premises in Obrenovac. The first two blocks have been reconstructed for the purpose of system supply which enable combined production of electric and thermal energies.

Thermal power plant Nikola Tesla B, situated 50 kilometers upstream of Belgrade has two strongest elctro-energetic units in Serbia and almost the whole of Europe which use low calory lignite and have separate powers of 620 MW each. This thermal power plant has proved iteslf as one of the support pillars in the Serbian energy system. Its blocks have set almost every record regarding production, non-stop operation within the system, hour exploitation and basic efficiency parameters and exploitation economy.

Thermal plant Kolubara A in Veliko Crljene operates within the corporate company Nikola Tesla A. It has been a part of the energy net of Serbia since 1956 with its five agregates of 270 MW total installed power. The latest and most powerful station in thermal plant Kolubara is block A5 with 110 MW nominal power. One of the current activities which marked the years 2008 and 2009 is the reconstruction of electrofilters and ash separation in block A5 in Kolubara power plant. The reconstruction of the electrofilter in block A5 sets as its goal the reduction of primary emission of solid particles into atmosphere, i.e. its reduction to less than 50 mg/m^3 of smoke gas, as stated in The Law on the Protection of the Environment of the Republic of Serbia, as well as in the law regulations of the Europen Union. The new, contemporary system for ash separation will use ten times less water for ash transport, the dumping space will be more resistent to ash spreading by the wind. Also, this will provide technical conditions to use ash as raw material in construction. What should not be disregarded is the positive effect on the protection of the environment and health of the local population living in the proximity of the dumping space.

The following production capacities operate within Corporate company Thermal Power Plants and Coal Mines Kostolac: open-pit mines Cirikovac and Drmno and thermal power plants Kostolac A and Kostolac B. Two blocks operate within thermal power plant Kostolac A: block A1 with 100 MW and block A2 with 210 MW. Two blocks operate within thermal power plant Kostolac B: block B1 with 348,5 MW which started production in 1987 and block A2 with 348.5 MW which started production in 1991 [7].

Thermal power plant Morava in Svilajnac was built on the rim of the area with pit coal mines, with the aim to use the finest coal fractions from these mines. It uses nine types of this fuel with different heat values. It is incorporated into the energy system at voltage levels of 35 and 110 kilowatts. Nowadays it mostly uses low calory coals from the open-pit mines of Kolubara and Kostolac.

When evaluating technical condition of the capacities of Elektroprivreda Srbije what one should bear in mind is, first of all, the age of the capacities and the obsolescence of technology. The average age of thermal energy units in the Republic of Serbia is 26 years. Nevertheless, even after rehabilitation and modernization, the technical condition of production capacities is still far behind the energy systems in the developed European countries.

Within the revitalization and capital rapairs on the blocks in thermal power plant Nikola Tesla A, blocks A1, A2, A4 and A5 were reconstructed and upgraded, which reduced the emission of solid particles in smoke gases within the limits of the European regulations (50 mg/m^3).The level of dust emission in thermal power plant Nikola Tesla A was reduced by 80% compared to the level in 2002. These high effects are mostly the cosequence of repairs on the two biggest sources of air pollution, i.e. the two oldest blocks in thermal power plant Nikola Tesla A where the emission of dust was reduced from 1.000-2.000 mg/m^3 to below 50 mg/m^3 of smoke gas.

The first phase of the new low water quantity system for collection, transport and dumping of ash and slag in thermal plant Nikola Tesla B (ash to water ratio is 1:1 instead of 1:15) was completed at the end of 2009. This new "denser" means of transport will reduce the surface of active boxes, the dumped mass will be resistant to spreading, and a drastic reduction of water quantity will reduce the impact on underground water. On the other hand, this will enable the separation and delivery of dry electrofilter ash for industrial purposes through special silos, without any risk od spreading by the wind.

In 2009 the reconstruction of electrofilters was completed and a new system for ash separation on block A5 in thermal power plant Kolubara in Veliko Crljene was installed.

When it comes to new thermal energy objects in the Republic of Serbia in the period up to 2012, Elektroprivreda Srbije predicts construction of new thermal power plants which use lignite from Kolubara, as well as construction of thermal power plants with kettles using low thermal capacity lignite. According to the Strategy of Energy System Development of the Republic of Serbia up to 2015, the production of electric energy in these new thermal power plants which use lignite with at least 4800 GWh a year in basic operation mode would provide safety and regularity in supplying the economy and citizens with electric energy without any significant import. Dynamic plan of strategy implementation in the domain of investments into new energy sources predicts their start in the period 2011/2012.

Every year thermal power plants Nikola Tesla combust over 20 million tones of lignite. The product of this combustion is over 3.5 million tones of ash and slag a year, which are deposited in open dump sites which cover the area of over 800 hectares, as well as 14.000.000 Nm^3 of smoke gas per hour (with full capacity operation) emitted into the atmosphere [10]. The plants used for purification are out of date which is why thermal power plant Nikola Tesla is conducting policy which sets as its goal ecological modernization and the increase of reliability of the existing equipment.

3. PROTECTION OF THE ENVIRONEMENT FROM WASTE MATERIALS FROM THERMAL POWER PLANTS

Large quantities of harmful materials are emitted during the combustion of coal which is why thermal power plants should be designed in such a manner that the emission of such materials be reduced to minimum or eliminated. Harmful materials known as PM2.5, carbon-dioxide, nitrogen oxides, sulphor-dioxide and heavymetals (mercury, lead and cadmium) in gases, ash and slag are emitted during the combustion of coal.

The European Union estimates that due to PM2.5 around 350.000 people die before their time in the countries which are members of the EU. It is also considered one of the most dangerous air pollutants. The most important sources of PM2.5 are diesel-motor gases, fuel oil, industrial processes and thermal power plant emission, ash from coal combution or dust spread from ash dump sites by the wind. Nitrogen oxides are formed due to high temperatures during combustion which combined with organic vapours and the influence of sunlight form smog. Nitrogen oxides, carbon-dixide and precipitation form "acid rains". Ash and slag dump sites can pollute underground water and jeopardize drinking water supply.

In 2003 the equipment for the continuous measuring of sulphor-dioxide and nitrogen oxide particles was installed in thermal power plants Nikola Tesla, blocks A3 and A5. The plan is to equip all blocks of this power plant with instruments which measure the emission of pollutants.

In 2008 Corporate Company Thermal Power Plants Nikola Tesla were certified for ISO 14001 standard. The application of this standard enables the incerese in technological and work discipline in the area of environment protection.

Thermic "pollution" in thermal power plants is the consequence of condensator cooling. Around 60 to 65% of heat produced in thermal power plants is released into the environment. If rivers are used as sources of cooling water, this produces negative influence on the life in the water.

Thermal power plants, especially those using lignite have a negative influence on the environment. At the end of 2000 the emission of solid particles, sulphor and nitrogen oxides in almost every thermal power plant in Serbia exceeded by far the permitted emission values, and ash and slag deposition as well as waste water treatment were not dealt with in a satifactory way. Duties originating in the domestic and European regulations state that all existing thermal power plants must conduct significant activities in the area of environment protection by 2015, which have getting ecological permits as their final goal. This is the reason for the start of numerous activities during the previous period, and the realization of the most important projects is currently in process.

3.1. Air protection

When exploiting coal and during the operation in thermal power plants harmful matters are emitted into the environment. The greatest air pollution occurs during coal digging in open-pit mines, its transport and reloading of coal and refuse ore. Refuse ore deposit sites can turn into major pollutants when strong winds blow if they deposit large quantities of sand and other fragmentary materials. As protective measures during transport and reloading, bilological recultivation of the refuse ore deposit sites are used. Also measures are taken to use mechanisation with reduced emission of fumes.

On the other hand coal combustion in thermal power plants pollutes air with harmful substances. Thermal enegy objects are major air pollutants since they use lignite from open-pit mines. Fumes containing SO_2, NOx, CO_2, CO and ash particles are released into the atmosphere through chimney stalks.

In the course of the last couple of years Elektroprivreda Srbije has started modernization of the existing environment protection measures in thermal power plants by adjusting the operation of electrofilters to the demands of the European Union regulations regarding the reduction of the emission and by replacing the technology for transport and depositiong of ash in deposit sites.

When adjusting the operation of these blocks to the demands of the law regulations, the priority was given to the reduction of particles from the oldest blocks and adjusting the operation of electrofilters to the demands of the European Union (50 mg/m^3). The condition of electrofilters has significant impact on air pollution in the surrounding of these blocks situated near settlements. It is, therefore, expected that the reconstruction of these electrofilters will have a considerable effect on the improvement of the air quality.

Another protective measure is the introduction of the desulphorizing plant with the aim to reduce the emission of sulphor oxides into the air. The concentration of sulphor oxides in the air around thermal power plants is within the given concentration values, this being the result of dilution in high chimney stalks.

Electrofilters installed in the objects that were constructed before 1970 had the efficiency of 98-98,5% of ash separation, while the objects which were constructed later than that had electrofilters with efficiency of 99-99.83%. The adjustment of the operation of electrofilters to the demands of the law regulations started in 2004 and nowadays, after

electrofilter reconstructions, 6 blocks meet the law norms of 50 mg/m^3. Particle concentration in smoke gases at non-adjusted electrofilters goes from 80 to 400 mg/m^3.

The concentration of sulphor oxides in emissions from these objects considerably exceed permitted values (400 mg/m^3) in all blocks of the thermal plant, while the concentration of nitrogen oxides exceeds permitted values (200 mg/m^3) only in blocks with power over 300 MW.

The emission of nitrogen oxides depends on the unit capacity of a thermal plant and the amount of nitrogen in coal and it increases with the increase of capacity, i.e. the amount of nitrogen. Values vary from 150-750 mg/m^3 with lignite thermal plants. The emission of harmful materials with thermal power plants – heating plants, particularly SO_2, is significant when these use fuel oil. When natural gas is used as fuel, there is no emission of pollutants which exceeds permitted values.

Years of experience at the existing deposit sites with hydraulic transpost and ash disposal point out to the problem of environment polluting by ash particle spreading by the wind, i.e. to the problem of the eolic ash erosion. Ash deposit sites are situated near settlements and fields which emphasises the need to carry out measures in order to protect the environment against ash spreading. Protective measures are carried not only at active boxes (water mirror, sprinkling system for dry surfaces, biological protection of new earthwork) but also at passive boxes (biological measures – planting grass). Current technology does not provide the necessary level of protection against ash spreading so this technology of ash and slag transport and disposal with water in ratio 1:10, the so-called rare mixture, is being replaced with a new one in ratio 1:1, the so-called dense mixture. This new technology of ash and slag transport and disposal reduces the influence of ash deposit site on the environment to the least possible measure, since the mass deposited by the new technology is resistent to spreading by the wind.

Papers about the influence of plants and equipments on the environment are written during the project phase after calculations on the intensity of the electric and magnetic fields in the environment. Based on these results, minimal distances from settlements and other objects are determined.

3.2. Water protection

All thermal power plants in Serbia are built in the vicinity of rivers, for they require great quantities of water. In the process of energy production, great quantities of waste waters are released. The types of cooling and support fuels (fuel oil or light fuel oil), transport technology and ash deposits, as well as the chemical preparing of water determine the type and quantity of waste water from thermal power plants and thermal power-heating plants. In cases when the liquid fuel is fuel oil or light fuel oil, these objects release waste water with a high content of oil, i.e. fuel oil.

Some thermal power plants with return cooling release waste water from the process of decarbonization. This water is suitable for ash transport and is used in thermal power plants of Elektroprivreda Srbije. All thermal power plants produce waste water in the plant for chemical preparing of water which is used in the hydraulic transport of ash and slag.

All thermal power plants use technology of hydraulic transport in their transport of ash and slag which does not provide the necessary level of protection against the influence they have on the surface and underground water due to overflows from deposit sites into

surface water and the infiltration of deposit site water into underground water. This is the reason why Elektroprivreda Srbije plans to replace the existing technology of hydraulic teansport of ash and slag with new technology of low water content transport. Positive effects of this new technology will be reduced water quanity used in transport of ash and deposit site water quantity. Thus there will be no overflowing and drain water shall be collected by draining system and reversed into the process. Besides, there will be no releasing of waste water into streams which will completely eliminate the problem of polluting surface water and water in the vicinity of deposit sites.

3.3. Soil protection

When producing coal, particularly with open-pit exploitation, large surfaces of soil are damaged which are later reused in different purposes through the processes of technical and biological recultivation. Elektroprivreda Srbije disposes with 8.500 hectares of land used in open-pit exploitation in the basins of Kostolac and Kolubara. Up to 1992 about 100 hectares were recultivated a year.

Difficult economic position and bad business stopped the recultivation activities from 1992 to 2001. A lot more attention has been given to this protective measure during the last few years. Spreading of ash by the wind and polluted underground waters pollutes the soil. In order to prevent this, biological recultivation of spare areas is conducted and the part of the operative area which is not used is sprinkled. Drains and wells with pumps are constructed around deposit sites in order to prevent the spreading of pollution and excessive wet in the surrounding soil.

According to the Law on the Protection of the Environment which came into force in December 2004, Elektroprivereda Srbije is obliged to adapt its work to the regulations of the Law by 2015.

CONCLUSION

Besides oil and natural gas, coal belongs to the group of main energy sources of the 20th and the beginning of the 21st century. When it comes to coal there are two main problems: resources are limited and its use pollutes the environment. Coal combustion, lignite in particular, leaves great quantities of ash and releases a great amount of harmful gases. The released carbon-diokside leads to the green house effect which leads to global warming.

Providing sufficient quantities of energy is one of the key conditions for development and survival of our civilization. One of the national priorities in the Republic of Serbia is reaching sustainable development which refers to the retional use of energy and protection and promotion of the environment.

According to the structure of coal resources in the Republic of Serbia, lignite is 16.3 billion tones of the total 16.7 billion tones of balance resources. Serbia produces 37.7 million tones of coal a year, 98% being lignite. Cosidering that thermal power plants make up to 70% in the structure of power plants, one can easily conclude that the greatest part of the coal produced is used in thermal power plants. Elecric power is produced in eight thermal power plants and three thermal power plant-heating plants in the Republic of Serbia. These plants are characterized by out of date technology and the average age of

26 years. However, Elektroprivreda Srbije has made great efforts during the past few years to reconstruct and modernize the existing thermal power plants and install electrofilters, desulphorizing plants and introduce technology of "low litre" ash separation. By installing electrofilters in blocks of thermal power plants, the emission of particles is reduced to 50 mg/m^3 which complies with the law regulations. New technology of low water quantity transport of ash and slag reduces the necessary water quantity up to ten times, making the surface of the deposit site more resistant to ash spreading by the wind thus creating conditions to use ash as raw material in construction at the same time reducing pollution of the environment. This increases thermal plant economy and reduces the level of pollution in the environment.

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UTICAJ TEHNOLOGIJE PRERADE UGLJA NA KVALITET ŽIVOTNE SREDINE

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Velika zastupljenost različitih vrsta ugljeva u proizvodnji električne i toplotne energije ukazuje na neophodnost njihovog korišćenja, a sa druge strane oni su glavni uzročnici zagađenja životne sredine. Tako se stvara apsurdna situacija da postupak i korišćenje uglja, čiji je glavni cilj bolji život i veći standard ljudi, vodi u degradaciju osnovnih životnih uslova.

U ovom radu analiziran je uticaj tehnologije prerade uglja u termoelektranama na kvalitet životne sredine. Cilj ovog rada je motivisanje primene ekonomski i tehnološki isplativih tehnologija za korišćenje uglja. Na taj način povećava se energetska efikasnost, što dovodi do smanjenja potrošnje energije i finansijskih ušteda, a time i povećanje kvaliteta životne sredine.

Ključne reči: *ugalj, životna sredina, energetska efikasnost.*