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THE ELECTROFILTER ASH OF GACKO THERMAL POWER PLANT AS TECHNOGENIC RAW MATERIAL AND THE IMPACT OF ASH WASTE PILEON THE ENVIRONMENT

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SUMMARY

During the working of thermal power plants, due to technological process of coal combustion, waste matter, which takes up large areas of land, degrades and pollutes the environment, is created. In the last years, a significant progress has been made in the world in researching new technologies that implement technogenic materials which have wide range of optimal economic use.An example for this is electrofilterash which is, as technogenic raw material,largly and more often used in building industry. This resulted in decreasing negative effects of ash which was deposited considerably on ash waste piles. The use of ash for different industry purposes decreases the costs, increases a company's profitand removes the negative effects on the environment and human health.

Key words: *electrofilter ash, cement, waste pile, the environment*

INTRODUCTION

Electrofilter ash represents the remains of ground coal combustion in thermal power plant boilers and similar plants. During electricity production process, the largest part of nonorganic matter remains as ash after coal combustion. A certain amount of slag remains at the bottom of the stove while ash accumulates on electrostatic filters.This is why it is called electrofilter or fly ash. The amount of electrofilter ash depends on ash composition in the fuel which burns itself out in the boiler, burning fuel temperature and the working of the filter. According to the estimates, thermal power plants produce 5-7 tons of ash per every 1000 KW of installed power, which represents the amount of ash for 24 hours.

There is the problem with solid waste material in the whole world as well as solid material waste piles and that is why the need to use it is highly important. Electrofilter ash represents 85% of all ash in thermal power plants [1]. The variety of burned coals in thermal power plants can contain elements in traces, which can be toxic in some cases. In lignite coal ashes, there are traces of elements like: arsenic, barium, beryllium, chromium, cesium, gallium, germanium, lithium, managanese, molybdenum, iron, rubidium, uranium and zinc. Most of these elements are toxic althought some of them can be useful (germanium).

ELECTROFILTER ASH CHARACTERISTICS

Electrofilter ash characteristics depend on the type of coal and the way of collecting ash from electrostatic precipitators. It is mostly fine, very small-grained, silt material. The colour of ash is usually grey and it depends on the content of $Fe_2O_3$and the amount of unburned coal in ash. Ash particles are of different sizes, mostly of spherical shapealthought there are, less commonly, particles of irregular shape.The size of ash particles has diameter of between 0,01 to 100μm, with the most common grain size of around 20μm. The ash can be classified into fine and rought fractions according to its particle size. If the size of the particle is below 45μm then the ash belongs to the fine fraction while every ash type with the particle size above the mentioned one belongs to rough-grained ash. The quality of electrofilter ash is considered to be its most significant characteristic.

Table 1.Granulometric composition of ash in GackoThermal Power Plant

Size class mm	Sample	
	Sample 1, %	Sample 2, %
-0,147 + 0,104	4,00	7,78
-0,104 + 0,074	3,21	6,33
-0, 074 + 0,053	19,29	7,75
-0,053 + 0,043	5,10	4,91
-0, 043 + 0,037	4,52	4,29
-0, 037 + 0	63,88	68,94

CHEMICAL AND MINERAL COMPOSITION OF ASH

Chemical and mineral composition of ash, which can be very different, depends on the type of coal that is used in thermal power plants, its composition, minerals tailings share in coal, etc. The ash contains these chemical compounds SiO_2, Al_2O_3, Fe_2O_3, CaO as the most important onesand also, in smaller amounts, the following compoundsMgO, MnO, Na_2O, SO_3, N, C, K_2O. Chemical compounds like TiO_2 and Pb_2O_5 are contained in some types of ashes.

Table 2.Chemical characteristics of ash in Gacko Thermal Power Plant

Compounds	Composition, %	
	Sample 1	Sample 2
SiO_2	4,50-4,38	8,08
Al_2O_3	1,42-1,65	6,69
Fe_2O_3	2,73-2,54	2,00
CaO	69,68-67,25	66,25
MgO	1,10-1,06	3,5
TiO_2	0,06-0,08	0,49
K_2O	0,74-0,63	0,95
Na_2O	0,51-0,48	0,32
SO_3	12,94-12,11	7,91
Loss due to fire	9,80-6,26	3,17

If we take the results given in Table 2 into consideration, we can say that electrofilter ash from Gacko Thermal Power Plant is specific because of its chemical composition where CaO has the largest share, i.e. 70%.

Mineral composition of ash contains nonorganic elements (crystalline and amorphous), organic matter and liquid and gas inclusions in organic and nonorganic elements. During coal combustion process, mineral-matter coal transforms itself into crystalline and amorphous phases which are parts of coal.Most of electrofilter ash is consisted of 70-80% of mineral matter in form of fine, spherical amorphous particles because of the fact that the ash cools quickly in thermal power plants. One part of electrofilterash is in the form of crystalline phases and the most significant ones, among others, are: quarz, calcite, hematite, magnetite and pyrite.

Mineral analysis of ash from Gacko Thermal Power Plant states that active matter CaO with minerals like cement, calcium silicate and anhydrous prevail in the composition of the ash.

Table 3. Concentration of heavy metals in ash from Gacko Thermal Power Plant

Element	Concentration, ppm		
	Hydraulic disposed ash	Ash without air	Ash influenced by air
Titanium (Ti)	-	-	403,6
Vanadium (V)	86,1	-	156,8
Chromium (Cr)	-	-	61,1
Manganese (Mn)	114,6	163,2	78,5
Iron (Fe)	8965,5	19100	12000
Cobalt (Co)	47,2	66,0	32,3
Nickel (Ni)	32,1	55,5	64,3
Copper (Cu)	25,2	30,8	23,0
Zinc (Zn)	38,4	37,6	38,1
Gallium (Ga)	8,6	13,3	6,7
Germanium (Ge)	5,3	11,9	4,7
Arsenic (As)	10,2	19,6	11,2
Rubidium (Rb)	2,2	15,8	6,5
Strontium (Sr)	615,9	1193,1	709,1
Lead (Pb)	48,6	-	13,7

After analysingelectrofilter ash from Gacko Thermal Power Plant, the presence of heavy metals was confirmed. These metals can have negative effects on air, water and soil if not, as such waste material, adequately disposed.

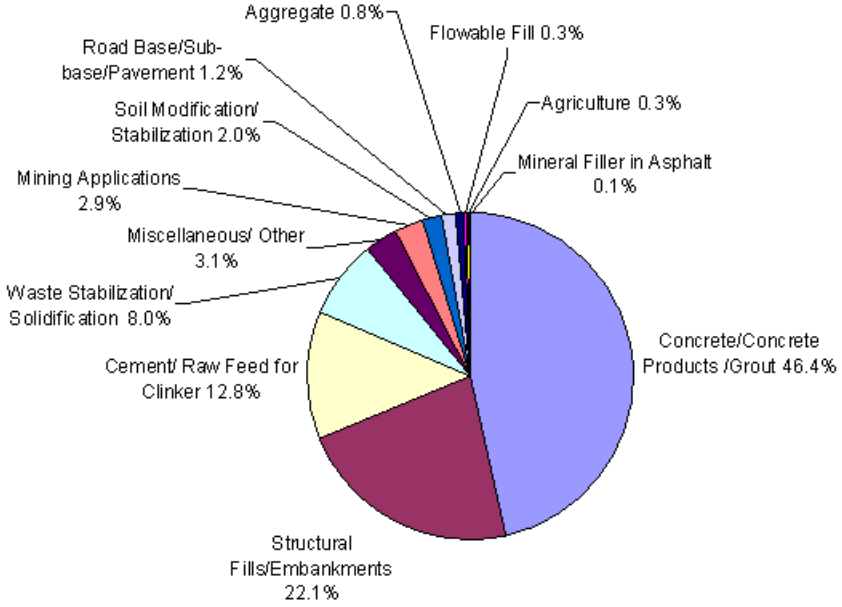
ELECTROFILTER ASH AS TECHNOGENIC RAW MATERIAL

Knowing that thermal power plants and other thermal plants emit large amounts of ash, the right question is if it is possible to use it for industry purposes.The production of ash within existing block of Gacko Thermal Power Plant, with 300 MW of installed power, is around 58,5 t/h, the maximum is 71 t/h. Considering effective annual 6000 working hours of the thermal power plant, the annual production of ash is 350 000 tons, the maximum is 426 000 tons [2].

Electrofilter ash as technogenic raw material can be higly significant in building industry, chemical industry and agriculture.Electrofilter ash with high share of silicon dioxide shows pozzolanic activity enabling it to build hydraulic compounds of calcium silicate hydrate with $Ca(OH)_2$. It is important to point out the fact that the largest amounts of electrofilter ash in the world are put in concrete as addidtional element when building banks as well as additional element to cement clinker.

Given the fact that electrofilter ash contains silicium oxide, calcium oxide, aluminium oxide and iron oxide, it can be used in the process of raw flour composition correction and as a substitute for

marl.Traditional concrete is made out of cement, sand, scree and water mixture. The use of electrofilter ash, obtained after coal combustion in high stoves, is of great significance because it decreases the use of cement in making concrete. The ash also improves performances and quality of concrete. It also improves the plastic features of concrete and its machinability, it decreases the amount of necessary water and segregation and influences the decrease of heat hydratation.



Picture 1. Standard use of electrofilter ash
Source: (http://rmrc.wisc.edu/coal-fly-ash/)

On top of everything, it increases the strength of concrete, decreases its perviousness and the corrosion of structural steel, but also increases resistance and decreases alkali-aggregate reaction. The concrete with the fly ash reaches its maximal strength slower than the concrete made out of just portland cement. The quality of electrofilter ash should be strictly monitored when used for the production of portland cement concrete. The most important concrete-related characteristics of this material are finenes, moisture, loss due to fire and chemical composition. The ash used for concrete must also contain enough pozzolanic activity and be of persistent quality.

The cement with electrofilter ash was difficult to obtain in the past, but today, it is often being introduced and used in the production of building materials, not just concrete, but also for the building of roads, dams, bricks as well as for the soil stabilisation which is necessary before meeting different engineering purposes.

Building materials which can be produced out of electrofilter ash are: lightweight concrete, building blocks, calcium carbonate elements, ceramic products like bricks, tiles and tubes. Large amounts of calcium carbonate bricks are being produced in some countries. Quarz sand is mostly being used as SiO_2 element and 8-10% of lime is being added. Given the fact that electrofilter ash from Gacko Thermal Power Plant contains large share of calcium oxide, it could entirely replace lime. Calcium-silicate bricks are of high quality and thus pruduced as even facade bricks.

Ceramic products like blocks, differend kinds of bricks and tiles are being produced out of different kinds of clay as basic raw material with quarz sand, ground marl and schist as addidtional elements.There is the possiblity of using electrofilter ash in the producion of ceramic products due to improving ceratin characteristics.Electrofilter ash can be widely used in brick industry. It is possible to replace 40% of clay with electrofilter ash in the process of brick production.If it is added to greasy kinds of clay, it decreases shrinking that happens during drying, which makes the ash a substitute for quarz sand. Because of its porous structure, electrofilter ash is very singnificant for the production of porous bricks.It is also very important to point out that lightweight ceramic products can be made out of clay and electrofilter ash using organic foam.

However, the biggest value of electrofilter ash is in the building of roads,modern highways, parking lots and airports.Being very light material, it is very suitable for the building of banks and as a filler in building asphalt mixtures.There is an entire list of electrofilter ash advantages when compared to natural materials and those advatanges are: it is much lighter than natural materials, which decreases the costs of transport and reduces soil subsidence, it possesses the ability of self-hardenening which means that it can reach desired firmness immediately after pressure.It is, also, possible to use the largest amount of electrofilter ash without any previous preparation when building roads.Its use in this industry is increasing on daily basis but mostly developed countries are using it.

The ash can be used in agriculture as a fertiliser and in melioration. Due to large amounts of $CaCO_3$, it would be especially useful to use it for calcification (on acid soil) as well as for improving soil composition beacuse it would make it more porpous and less compact.When using the ash for these purposes, the presence of toxic metals and radioactivity should be monitored [3].

Using electrofilter ash in engineering and roadbuilding would significantly decrease the amount of ash on the waste piles, which would positively affect the environment and considerably save money, at the same time, in engineering.

ASH WASTE PILES AND THEIR IMPACT ON THE ENVIRONMENT

Ash waste piles take up large areas of land. Electrofilter ash creates a lot of problems which are especially detrimental to the environment. Waste piles cause pollution of air, surface and ground water, degrade agricultural soil and have detrimental effects to flora, fauna and ecosystem. Ash particles can cause immediate detrimental consequences for human health and the environment. They are spread by wind to much farther areas than the thermal power plant area is itself. The particles can stay long in the air, which increases the chance of inhaling them.

The ash from Gacko Thermal Power Plant was disposed to waste pile called Dražljevo, 6 km away from thermal power plant, fromits founding till 1996. The waste pile is located at the foot of Čemerno pass. Dražljevo waste pile takes up an area of 18 ha with capacity to pile up ash to1600 m above-sea altitude. The ash from the thermal power plant was transported by tracks to Dražljevo and disposed by implementing different technologies, which underwent changes due to manifested problems. In the beginning, waste pile area's bank parimeter at 1142 m above-sea altitude was filled with water into which the ash was disposed from the tracks. Then, the process progressed to the use of autocisterns from which the ash was injected pneumatically under the water level. The manifested problems related to the clogging of pipeline resulted infree emittting of ash into air after building bank parimeter at 1146 m. This caused a real ecological disaster because the wind blew ash particles around wider area than the thermal power plant area was. By reaching the heights of 1146-1148 m, the process was changed and switched to hidraulic disposal in the form of thick hydromixture and implementing cooperative extension method. This method enabled building bank parimeter using disposed ash without building hydroisolation.Hidraulic system was projected to upgrade to 1153 m by implementing gravitation transport of prepared hydromixture [4].

It was planned to upgrade it to 1160 m, after which the use of waste pile would not be justified due to considerable decrease of available area as well as extensive remedial measures necessary for its stability. 1160 m were reached in 1992 which resulted in 3,5 million tons being disposed to Draželjevo waste pile [5].

Evan thought considerable resources were invested into the development and maintainance of Dražljevo waste pile, the area around the waste pile is partly degraded. The problem of environment pollution is considerably decreased by implementing hydromixture technology. Due to mixing ash and water, relatively high temperature is reached (80-100°C) while chemical processes in the waste pile can take very long. Alsowaters that get mixed with the ash in the waste pile become basic ($pH \geq 12$). Because of all the aforementioned facts, the waste pile must be registered as an object which

endangers vast area. The process of ash and slag disposal is finished at the Dražljevo waste pile as well as technical phase of recultivation after which grass was sowed. However, this waste pile, as 'ecological charge' over Gacko, must be controled and maintained.

Cassette I has been used for ash and slag disposal from Gacko Thermal Power Plant since 1995. This ash waste pile is put in a digging area of the Gračanica surface digging site. The transport of ash from thermal power plant to the area of internal disposal space of the surface digging site is done pneumatically by means of iron pipelines. A device used for preparation of hydromixture is placed on the perimeter of surface digging site near the hydromixture disposal area. The water is brought to this device, besides ash, and thus hydromixture with 33% of firmness is created. This hydromixture goes to shaft and then with HDPE pipline DN 25 is taken with gravitation to subcassette where ash pours out. Hydromixture is disposed in thin layers while free waters are being taken from the waste pile to the disposal shaft and further to water-returning pump station by means of iron pipeline. The transport of this returning water is done with three pumps and appropriate pipe fittings through two HDPR pipeline DN 100 to the device used for preparing hydromixture. Cassette II, on which 4 523 020 m^3 of ash are planned to be disposed [6], is located south of cassette I and takes up an area of around 170 000 m (17 ha).

Picture 2. Internal disposal site of electrofilter ash (Cassette I i II)

Every time the plant for preparation and transport of hydromixture stops working, the entire system, i.e. all the equipment used for hydromixture is washed out. This is carried out at the end of the working day when ash dosing stops in the conditioner and the process continues only with water. When a man in charge determines that the system is washed out, the water in the hydromixtureconditioner is stopped while the remaining amount of water in the pipeline is being redirected to drainage cassette by opening vent for about 50 m. The drainage cassette with volume of 250 m^3 is on the ouside of the waste pileand it is linked to the pump station of filtered and drain water.

Ash waste pile on cassette II is formed as an extension of cassette I towards coal trasporter so the waste pile is shaped on the south side by existing transporter while on the north side with existing waste pile and on the east side with geological profiles 5 and 17.

Cassette II, as well as cassette I, is formed on the Neogene sediments which are, based on their composition, hydroisolating.In the sector where the waste pile is located, the emergence of bigger and deeper faults is not registered. The faults registered during coal exploitation are shallow and not related to big Dinaric fault. There is a 50-centimeter marl layer over this shelf layer. This layer of marl represents solid hydroisolating layer since earlier researches proved that its porosity coefficent was 10 cm/s. The existing layer of marl can be a good foundation for putting water-resistent foil. Hydroisolating foil which is placed on the waste pile before ash disposal is type HDPE, thick 1 mm.

This foil is meant for wrapping hazardous materials so its basic quality is incredible elasticity which prevents it from damaging in case of disposed material subsidence over time. The foil is put on the cassette II/1 foundation, on the inner slopes of initial bank and on the outside slopes as well as the top of initial cassette I bank thus making links with existing foil on the inner bank of initial cassette I bank. This separted the waste pile completely from natural ground. The process of putting the foil was realised in two phases, i.e. the foil was put on the waste pile foundation and inner banks of initial subcassette II/1 bank during the first phase while in the second phase, after transition from ash disposal to subcassette II/1, the foil was put on slopes of existing cassette I bank and its top and the link with the existing foil was made [7].

Unfavorable influence of ground water is seen in the possibility of elevating the ground water level and creating the force which can have detrimental effects on the object's stability. The detailed study of the terrrain found the sources of ground water stream, which were influenced by the construction of water-catchment objects. They are steered in a controlled manner out of the waste pile edges to the existing water-catchment object.

Aiming to control all waters from and around the waste pile, the drainage system for collecting and steering filtered water from the waste pile itself was built. If by any chance ash hydromixture, which is trasported to the waste pile, contains larger amount of water than necessary for the chemical process of ash hardening and its transformation into calcium carbonate, there will be more free water than necessary. Together with water collected from precipitation, which tends to infiltrate and contaminate itself by passing through ash mass, this technological water redundacy would go towards the bottom of the waste pile and it would stick there given the fact that the bottom and sides of the waste pile are not purous. This would decresase the stability of the waste pile. In order to prevent this, one more drainage system is installed within the waste pile with the aim of collecting and disposing all filtered waters from the waste pile. The system for disposing water coming from either tecnological process or precipitation was projected. This system is consisted of spillway pipes placed on three height levels, small channel in which water from spillway pipes pours in and from which it gets steered away to drainageshaft where by means of pipes gets to the returning-water pump station.Spillway water gets transported by pipes from drainage shaft to returning-water pump station [7].

The protection of waste pile from surface water means protection from precipitation. To prevent its flow as well as its tendency to stop over and even form smaller types of accumulation which can endanger the stability of waste pile, two channels were built to protect the waste pile from north and south side.

Studies confirmed that the quality of ash disposal depended on the thickness of layer formed while pouring out and that the maximal thickness of layer should be 20 cm. If the thickness of layer gets decreased during disposal, the process of hardening gets faster and with that the consistency of the disposed mass. The studies also found out that the ash was very active, literally increasing pH values of water which were intensified through contact time. If water was highly diluted, from 1:500 to 1: 1000, we would get the water whose impact on the environment would be insignificant [7].

During low-intensity precipitation, absolute absorption of all water takes place but high-intensity precipitation causes the water to pour down the outter slopes of deposited and hardened ash increasing its pH value along the way. It was concluded according to the results that short-term contact of precipitation with hardened ash did not increase pH value while long-term contact did increase pH value, the value of 8,5 to 8,8.

CONCLUSION

Non-renewable enegry resources presented by lignite and dark lingite coals with the lowest carbonified level can be found in Gacko coal mine. They produce large amounts of ash after the process of coal combustion in the boilers of Gacko Thermal Power Plant due to mineral and chemical composition of fuel. The ash is the most present unused secondary waste matter which can also beused

as a substitute for other materials. The use of ash in engineering, first in civil engineering (road building) then in high-rise building construction (the production of cement, building bricks) and for other purposes (correction of pH value of soil) would considerably decrease ecological problems due to decreased amount of disposed ash and increase of economic efficiency of companies. Besides, the use of electrofilter ash for commercial purposes, on the territory of Republic of Srpska, would decrease exploitation of natural materials of similar chemical composition such as sand and scree. The use of electrofilter ash is one part of sustainable use with the aim of preserving natural resources and the protection of the environment but also the foundation for making new building materials based on recycling side product.

When disposing electrofilter ash on the waste piles, contamination and degradation of the environment take place. In order to protect the envoronment to a certain extent, it is necessary to undertake a list of activities. The most important ones are:

- The control of electrofilter state in order to protect air;
- Putting hydroisolating foil when conducting work on putting hydroisolating foil on the ash waste pile, obligatory check of joint place of hydroisolating foils, i.e. the place where hydroisolating foils are welded. All welded places must be stitched well to prevent the flow of decontaminated water from the ash waste pile into surface and ground water;
- Recultivation and sanitation of eroding channels by applying bigger layer of humus on the entire area of waste pile;
- Technical, agrotechnical and biological recultivation after which the spreading of ash by wind will be stopped and thus the air pollution;
- To collect precipitation waters using drainage system placed above hydroisolating foil;
- To establish piozemeter drilling network around and in the waste pile and control the level and quality of water.

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REFERENCES

[1] Baščarević, Z., Komljenović M., Petrašinović-Stojkanović, Lj., Jovanović N., Rosić A.,Ršumović M. (2006). Ispitivanje svojstava elektrofilterskog pepela termoelektrana u cilju njegove upotrebekao sekundarne sirovine za proizvodnju portland cementnog klinkera. Beogarad, Hemijska industrija, No 9 – 10 str. 245-252.

[2] Dokumentacija TE Gacko. Dopunjeni plan aktivnosti sa mjerama i rokovima za postepeno smanjenje emisije odnosno zagađenja i za usaglašavanje sa najboljom raspoloživom tehnikom. Banja Luka, Institut zaštite, ekologije i informatike, 2008.

[3] Crnogorac, Č. (2006). Geografske osnove zaštite životne sredine. Banja Luka, Prirodno-matematički fakultet.

[4] Problematika deponovanja pepela TE Gacko. Sarajevo, Elektroprivreda Bosne i Hercegovine, 1990.

[5] Dokumentacija TE Gacko. Obim poslova na unapređenju ekološkog uticaja Rudnika i TE Gacko na okolinu po osnovu projekta finansiranja POWER III. Gacko, Fond stručne dokumentacije Rudnika i TE Gacko, 2001.

[6] Stojić, P. (1991). Deponija pepela „Gračanica“. Sarajevo. Zavod za vodoprivredu.

[7] Dokumentacija TE. Dokaz uz zahtjev za izdavanje ekološke dozvole, Banja Luka. Institut zaštite, ekologije i informatike, 2008.