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RAZVOJ PROIZVODA I POSTROJENJA ZA PROIZVODNJU FILTER-ANTRACITA U RUDNIKU ANTRACITA VRŠKA ČUKA

DEVELOPMENT OF PRODUCTS AND FACILITIES FOR THE PRODUCTION OF FILTER-ANTHRACITE IN THE ANTHRACITE MINE VRŠKA ČUKA

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Rudnik antracita Vrška Čuka je jedini rudnik antracita u Srbiji. U potrazi za alternativnom upotrebom antracita, u proteklih nekoliko godina sproveden je niz aktivnosti, od ideje i razvoja proizvoda do projekta izgradnje pogona za proizvodnju filter-antracita. Filter-antracit kao novi proizvod je šansa za rudnik, sa kojom rudnik može da doživi lepšu budućnost. Projektovano postrojenje je u skladu sa aktuelnim ekološkim standardima. U radu je prikazan razvoj proizvoda i postrojenja za proizvodnju filter-antracita u rudniku antracita Vrška Čuka.

Ključne reči: *voda; filterski-materijal; postrojenje; antracit; Vrška Čuka*

The anthracite mine Vrška Čuka is the only anthracite coal mine in Serbia. Looking for an alternative use of anthracite, in the past few years a series of activities have been carried out, from the idea and product development to the project of building a plant for the production of filter-anthracite. Filter-anthracite as a new product is a chance for the mine, with which the mine can experience a prospective future of its own. The projected process is in accordance with the current environmental standards. The paper presents the development of products and facilities for the production of filter-anthracite in the anthracite mine Vrška Čuka.

Key words: *water; filter-material; facilities; anthracite; Vrška Čuka*

1. Introduction

Water and coal are the most valuable natural resources. They have a crucial and a vital role in meeting current needs mankind and it will be a resource bridge to meet economic and sustainable development goals in the future.

Water is the key and most important resource of the 21st century. It is the most precious resource associated with meeting basic human needs. In many regions, the amount of clean drinking water is declining due to population growth, urbanization, changes in lifestyle, economic development, pollution and climate change. One of the most important tasks is the prevention of pollution as well as

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the purification of drinking water. Globally, at least 2 billion people use a contaminated drinking water [1]. Also, more than 80% of wastewater resulting from human activities is discharged into rivers or sea without any treatment [1].

On the other hand, coal was, is and will be the most important source of primary energy worldwide. It has been the world's fastest growing energy source in recent years [2]. Anthracite coal is a type of coal with high carbon content, low moisture content, and excellent heat-generating properties. It is the highest grade of coal and is often referred to as "hard coal."

Anthracite coal accounts for about 1 % of the world's coal reserves [3]. It is mined in only a few countries around the world. The top producers of anthracite coal in the world were China, Russia, and Vietnam [4]. It's worth mentioning that anthracite coal production also takes place in other countries, albeit on a smaller scale. These countries include Ukraine, Poland, North Korea, and the United States [4]. In Republic of Serbia, it had been also mined in the coal mine Vrska Cuka, Avramica. However, it's important to note that anthracite coal production can vary over time due to changes in demand, economic factors, and environmental considerations [5].

Anthracite is commonly classified into three grades: standard grade (SG), high grade (HG), and ultrahigh grade (UHG) [6]. Anthracite coal has a wide range of industrial applications such as [6]:

Heating: Anthracite coal is used as a fuel for residential, commercial, and industrial heating. It is an efficient and clean-burning fuel for stoves, furnaces, and boilers, and it produces intense heat and provides long-lasting, steady warmth.

Metallurgical Uses: Anthracite coal is used in the production of steel and other metals. It is a key ingredient in the production of coke, which is a fuel and reducing agent used in the iron and steel industry.

Water Filtration: Anthracite coal is used in water filtration systems. Its porous structure allows it to act as a natural filter, removing impurities and contaminants from water. It is commonly used in municipal and industrial water treatment facilities for processes such as filtration and adsorption.

Home Decor and Crafts: Anthracite coal has been used for decorative purposes and in crafts. Due to its shiny, black appearance, it is sometimes polished and used as a decorative stone in jewelry, sculptures, and ornamental objects.

The usage of anthracite coal has been declining over the years due to environmental concerns and the global shift towards cleaner energy sources. Although its potential for water treatment has been recognized since ancient times, anthracite coal was not used for this purpose until the beginning of the 20th century.

Filtration is one of the most used methods for water treatment. The removal of suspended and colloidal particles by filtration is based on their deposition on the surface of filter grains while the water flows through a bed of these grains (filter media). The quality of the filtrate depends on the size, surface charge, and geometry of both suspended solids and filter media.

Anthracite coal is commonly used as a filtering medium in water treatment processes, specifically in water filtration systems. Its unique physical and chemical properties make it an effective material for removing impurities and contaminants from water.

The advantages of using anthracite in water filtration include its high porosity, which allows for excellent particle retention, and its resistance to breakdown over time. It also provides a large surface area for biofilm formation, enhancing the biological filtration capabilities of the system [7].

Anthracite coal is used mainly as an upper layer of materials in dual media for water filtration. European Standard EN 12909 defines the quality of anthracite used to purify water intended for human consumption and prescribes methods for testing the characteristics of anthracite. The standard

was approved by the CEN of the European Committee for Standardization, July 16, 1999. The effective size, uniformity coefficient, specific gravity, acid solubility and hardness are the main physical properties. Anthracite coal would remove bacteria, certain colors, odors and tastes more efficiently than sand. It has a good adsorptive characteristic, too.

It is important to note that the careful selection of the anthracite source and monitoring of water quality are essential to ensure safe and effective water treatment. Additionally, in recent years, there has been an increased focus on using more sustainable and environmentally friendly filtration media, such as various types of activated carbon and alternative mineral-based filter media.

2. Anthracite mine Vrška Čuka

Anthracite coal mine “Vrska Cuka” is located about 10 kilometers near Zajecar in Eastern Serbia. It is the smallest underground mine in Serbia measured in terms of level of production (about 5,000 t coal). Coal mine "Vrška Čuka" has been operating for more than 130 years with average annual production of between 10 and 12 thousand tonnes. In the 1950’s, this mine produced 55,000 tonnes of coal per year.

Anthracite coal mine “Vrska Cuka”is the only mine of anthracite coal in Serbia. Currently, it produces anthracite in the Mala Cuka deposit. Total geological and exploitation reserves (A + B + C1 category) in the "Mala Čuka" accounts 1,469.325 t and 1,395,859 t, respectively [8].

In the coal mine “Vrška Čuka”, anthracite generates in two varieties as amorphous and crystallite anthracite [9].

Currently, in the present state of exploitation, production and marketing of anthracite to consumers as an energy source, there is a question of sustainability and closure of the mine in to future. Based on available data and current projections into future, the sustainability of mining production is based on the production of new filter material product known as filter-anthracite [10].

2.1. Filter-anthracite

The first tests and use of anthracite for the purification of drinking water began in 1994 in cooperation with Trial from Kruševac. The results showed very good qualitative properties with the possibility of replacing activated carbon [11].

The long-term cooperation of the Technical Faculty in Bor led to the development and application of a new product in drinking water purification technology, called " filter-anthracite".

Filter-anthracite is a natural filter material, produced from crushed and sieved highest quality crystallite anthracite without chemical and thermal activation process.

Filter-anthracite is a resistant to abrasion. It is characterized by metallic-glass shine, with shell texture and inner porous structure, which makes it suitable for water filtration.

Filter-anthracite meets the requirements of the European standard EN 12909 (in accordance with ANSI/AWWA B100-09) and in terms of the controlled parameters; it is health safety and can be used in the water purification process for drinking-water (Certificate no. 178 of 11.04.2014 by Institute of Public Health "Dr. Milan Jovanovic Batut") [12-13].

Filter-anthracite® is an effective water filtration media for single – or multi-layer filtration in the open and closed filters. It is used in the water purification for drinking-water and swimming pools water [12-13], and wastewater [14-15].

According to the quality and physical and chemical characteristics of anthracite coal, new, eco-friendly product, filter-anthracite with low ash content and high cost price, has made a concrete contribution to the improvement of the economic and production effects of coal mine "Vrška Čuka". All

mentioned will have a wider benefit on the social, economic, regional and sustainable development of the coal mine in the future.

2.2. Facility for the production of filter-anthracite

The facility for the production of filter-anthracite is located in the industrial zone of the Vrska Cuka mine, between the coal separation plant and the bunker for finished products (figure 1) [16].

The facility for the production of filter anthracite consists of several separate technological units: Drying of separated anthracite up to 8% moisture, Crushing and sieving of dry anthracite, Line of transport and packaging of finished products. Between individual technological units there are bunkers that serve to eliminate differences in capacities and different modes of operation between individual stages of the process.

Technological scheme of the facility for the production of filter anthracite is given on Figure 2 [16].

The facility for the production of filter anthracite is designed in such a way as to enable smooth operation of the separation without downtime. In addition, the operation regimes of the plant according to the stages of the process of coal preparation and filter anthracite production are harmonized with the operation regime of separation so that the necessary capacities are smoothly ensured in each plant separately, as well as in all of them together.

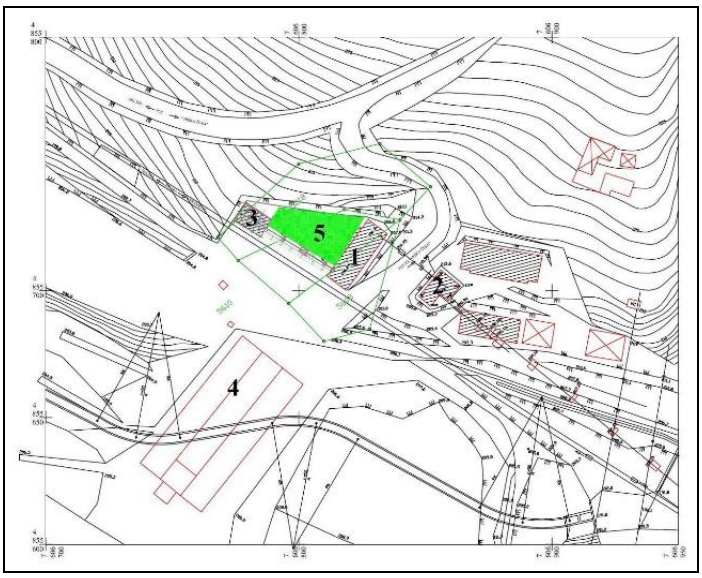

Figure 1 Situational plan of the "Vrska Cuka" mine with a view and location of the buildings (; 1-Coal separation building; 2-Crushing building; 3-Bunker of finished products; 4-Sedimentation basins; 5-Plant for the production of filter-anthracite

The basic raw material in the production process of the filter-anthracite is separated coal, which is obtained as a finished product of two-stage gravity concentration in the coal separation plant. The plant produces different commercial products of filter anthracite, namely: (-2.5+1.6) mm and (-1.6+0.8) mm. Fractions below 0.8 mm are a by-product with an ash content of up to 5%, which is also packed and stored in the warehouse of finished products. The project envisages equipment for drainage and purification of drying gases [16].

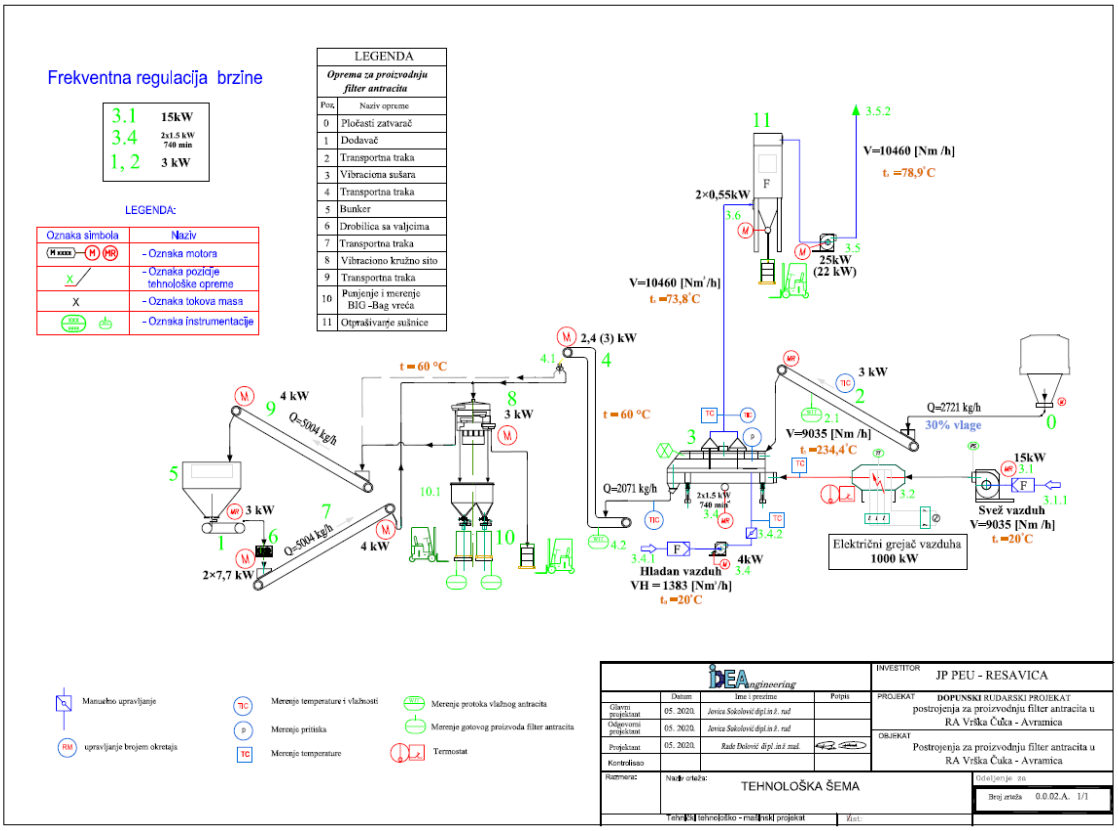

Figure 2 Technological scheme of the facility for the production of filter anthracite

2.1.1. Investment for the purchase of equipment

The total investment funds for the purchase of equipment and the execution of work amount to EUR 2,448,605.8 (including VAT).

Table 1. Total investments [€]

Investments	*Total investments* [€]	*Total investments* [%]
Investments in mechanical equipment	912 202,52	44,7
Investments for the construction part	257 494,89	12,6
Investments for TS 10/0.4kV, 2x630kVA	632 491,33	31,0
Investments for grounding, lighting and sockets	10 756,82	0,5
Investments for management equipment	227 559,42	11,2
Total investments in the plant	2 040 504,90	~100
VAT 20%	408 100,98	2
Total investments in the plant including VAT	2 448 605,8	44,7

Costs that are not included in the above table include the costs of creating and verifying technical documentation, costs of construction supervision, costs of tendering, rental of storage equipment (cranes, etc.), for temporary facilities, taxes, insurance, transport of equipment, etc.

2.1.2. Time needed for construction

In order to form the basic plan of the project, it is necessary to make three independent plans, namely: a plan for the preparation of technical documentation, procurement of equipment, and construction. By integrating these three plans, the master project schedule is formed.

The creation of technical documentation (engineering) "covers" the activities of design, i.e., detailed engineering in all its segments (process, mechanical equipment, instrumentation, electrical, construction, architectural, steel structure, insulation, and painting).

Procurement of equipment includes purchase, relapse (monitoring and control of equipment manufacturing deadlines and documentation), inspection (during equipment manufacturing and its final quantitative and qualitative acceptance), and transportation.

Construction is a set of all activities on the construction itself (construction work) and assembly (mechanical, installation) up to the so-called mechanical completeness of the plant, which is followed by the previous actions before commissioning ("precommissioning"), testing of individual systems ("commissioning"), and commissioning of the plant itself. The estimated time required for the acquisition of equipment and the construction of a filter-anthracite production plant is 12 months.

2.1.3. Financial effect of investment

For the projected processing capacity of about 2 t/h, the expected total revenue from the sale of filter anthracite on an annual basis amounts to 2,356,225.36 EUR, or without VAT, 1,963,521 EUR.

A large ratio of the price of the output and input product, that is, the sale of anthracite flitter, and the price of the input raw material, which in our case amounts to: 951.55 / 84.13 = 11.31.

1. The market price of the input raw material (separated coal) is 84.13 EUR.
2. The market price of the anthracite filter output product is 951.55 EUR.

Total processing costs are relatively low (table 2).

Table 2. Total processing costs [€]

Costs	*Processing costs* [€/per year]	*Processing costs* [€/per ton]
Total labor costs	46 130.04	18.63
Total electricity costs	53 865.47	21.67
Total cost of materials	7 829.66	3.15
Total processing costs:	**107 825.17**	43.45

2.1.4. Investment payback time

The investment payback time is two accounting years, i.e., two years of anthracite filter production, which represents an extremely short term.

3. Conclusion

In operation, the filter-anthracite production facility, along with the anthracite mine, separation, and other installations, form a financially self-sustaining unit, with the possibility of only financing development projects such as environmental protection, improved working conditions, new mining equipment, or product adaptation to market requirements.

The major equipment was not contracted at the time of technical documentation development, resulting in the generality of technical solutions in the project documentation. As a result, additional information from the equipment's supplier must be added to the technical documentation.

The projected process complies with current environmental regulations. The project has a local socioeconomic impact, as well as some alignment between some project goals and EU development strategies. The construction of a facility for the production of filter-anthracite envisages the creation of six new jobs in the plant and 40 new jobs in the Vrska Cuka anthracite coal mine for the local workforce, allowing the transition of anthracite as fuel into a technological raw material, filter-anthracite for water purification, without any socioeconomic consequences.

The future of mining output in the underground anthracite coal mine "Vrska Cuka" is based on the development of a new, environmentally benign product, filter anthracite, which will be utilized in water treatment.

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