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THE POSSIBILITIES OF USING SAPROPEL FOR BRIQUETTE PRODUCTION

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Abstract. This article describes the possibilities of using renewable energy fuel sources for the purpose of producing thermal energy. One of the options (alternatives) is to use sapropel (lake sediment biomass) not only as a fertilizer, feed additive, binder etc. but also as an energy fuel. One of the first steps to material extraction and preparation is fuel briquette (direct extraction of useful heat) production, technology and methodology. The article compares the author's findings with analytical and experimental results obtained by other scientists.

Keywords: sapropel, briquette, briquettes production, CO, NO_x, produce.

Introduction

The global warming issue caused by CO_2 and other substances has become the greatest concern worldwide in recent years. To protect forestry resources as a major absorbent of CO_2, control over ever-increasing deforestation along with an increase in the consumption of wood fuel such as firewood and charcoal is an urgent issue. Thus, the emphasis is put on the development of a substitute fuel for charcoal.

To this point, briquette production technology is environmental countermeasure technology, or clean coal technology, providing a stable supply of briquettes to contribute to the prevention of flood damage and the conservation of forestry resources. There is need for other possibilities of using other natural resources of materials (peat, sapropel, etc.).

Structuring processes occurring during dewatering the molded organo-mineral materials of biogenic origin (peat, sapropel, etc.) have common regularities. This is due to the group chemical composition of these materials (containing humic and fulvic acids, readily hydrolyzable substances, non hydrolyzable residue, trace elements, etc.), particle size distribution (0.5–300 mm), and their high ion exchange activity. Besides, the structure depends on the ratio between the organic and mineral matters of the solid phase. This ratio mainly affects the properties of sapropels since the ash content of those, unlike peat, can reach 85–90%.

Sapropel is a product of mechanical, physical, chemical and biological transformations of the remnants of lacustrine plants and animals as well as inorganic components of biogenic origin. Owing to colloid structure, sapropel acquires the properties of a natural sorbent after removing free water. The organic matter of sapropel (~75%) determines its important properties such as biological activity, biochemical resistance and adhesiveness (Кирейчева, Хохлова 1998; Kireicheva, Khokhlova 2000; Baltrėnas *et al.* 2009; Kozlovska-Kędziora, Petraitis 2010a). In addition, the organic matter acts as a catalyst for the oxidation processes of heavy resins at the coal–binder interface. It has been shown (Nikolaeva *et al.* 2009) that sapropel has high adsorption capacity for short residues on the order of 70–75%.

Briquetting is a process of transforming loose material into the solid material, called briquette. The briquetting material may be added or have no added substance. The briquetting process is widely used in industry. Using press briquettes includes fine coal and lignite, peat, sapropel, sawdust, metal shavings, ores and ore concentrates, etc. (The production... 2008; Production of... 2007; Kozlovska-Kędziora, Petraitis 2010a).

Methodology of Making Briquettes

Raw materials undergo briquettes and have very specific characteristics and parameters, because of the briquetting process itself, storage and incineration. The most important of those are as follows:

- moisture content should fluctuate within the range of 8–18%. It is very important that the same briquetting (in case it is too hot, a briquette is blown by rapidly evaporating water of a very low quality) parameters used for the energy generating during the combustion;

- an appropriate fraction – the briquetting process runs smoothly due to larger surface adhesion molecules bonded in the briquette;
- the material type for briquette, its density, the ability to bond under the influence of particular pressure and temperature;
- appropriate physical and chemical properties such as the calorific value, the heat of combustion, the chemical composition of the material before and after combustion, ash content.

Following the above requirements often used for briquetting, the material must be pre-seasoned or desiccated in special ovens.

Shredded organic materials contain mostly cellulose, starch, protein, resins, fats and waxes. During compaction, including a simultaneous action of temperature, humidity and high pressure, these substances undergo various physical and chemical transformations such as starch gelatinization, protein gelatinization, melting resin and lignin, etc. As a result of these phenomena reduce the friction between the particles of material. This affects individual pressures to reduce compaction, thereby decreasing energy consumption and the process is to improve the mechanical properties of the finished briquette (Raw materials… 2007; Петрова *et al.* 2007; Косов, Беляков 2004).

The easiest way to test if material is suitable enough for producing a good briquette is to soak it in water, grab a handful of the material and press it into a ball in hands. If the material forms into a ball that retains its shape and does not fall apart, it will press into a good solid briquette.

Some people prefer using a binding agent in their recipe in order to increase the binding capacity of their materials. Some good options include fish waste, molasses, wood ash, manure, corn starch or wheat starch and sapropel. Most materials will not need a binding agent if you build a press that is able to exert a sufficient amount of pressure.

Experiment with materials that are locally available in order to come up with a good briquette compound. Also experiment with the proportions of your compound until you come up with a good, long-burning briquette. For example, 100% of shredded newspaper will work for making briquettes; however, they burn better if you add some small woodchips or a small amount of crushed charcoal.

After pressing, the briquettes are moisturized. An important point is to fully dry them before using for fuel. A few days in the hot sun should be sufficient. When burning the briquettes, we usually break them apart rather than burning them whole. Breaking them creates more surface area and causes them to burn hotter (Dahlman, Forst 2001; Alkan *et al.* 2009; Kozlovska-Kędziora, Petraitis 2010b).

One of the most important steps in producing briquettes is pressing biomass.

The first press described in this technical note is built almost entirely out of lumber, thus, building materials are easy to find. The press is very similar to that originally designed and built by Dr. Ben Bryant from the state of Washington (Fig. 1) (Dahlman, Forst 2001).

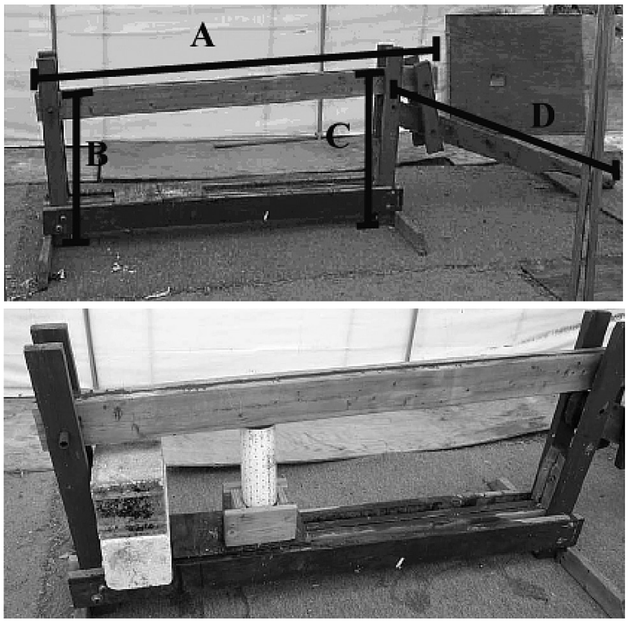

Fig. 1. Measurements of the briquette press: A – 215 cm, B – 80 cm, C – 85 cm, D – 180 cm (Dahlman, Forst 2001)

Pressing is achieved employing a simple lever mechanism that is easily understandable and does not require specific parts (as opposed to screw and hydraulic jack presses).

However, the press is quite large and heavy, and therefore can be hardly moved to transport and requires two people to run it efficiently. Also, this design only allows for pressing briquettes while some other designs can also be used as oil presses.

The next press discussed is the one that uses a Car Jack to exert pressure. The foot of the Jack has been removed in order to allow it to fit inside the briquette mold. Dimensions for the frame of the press are presented below (Fig. 2) (Dahlman, Forst 2001).

The briquette mold can be prepared in the same fashion.

Place the mold under the frame and secure the jack between the crossbar and the briquette mold.

Fig. 2. "Car Jack" type briquettes press. Measurements for the press A – 70 cm, B – 15 cm, C – 90 cm, D – 30 cm, E – 55 cm, F – 5 cm (Dahlman, Forst 2001)

Material and Energy Balance

Before material and energy balance is carried out, first, a decision on an operating system to form the basis of the analysis must be made. The system representing an ideal briquetting plant is presented in Fig. 3. The function of this system is to take feed, process it and make it suitable for the preheater.

Accordingly, this subsystem comprises sieving, grinding or drying or both (depending upon raw material), storage and conveying to the feed preheater (2). During pre-processing, 1 percent loss of material and moisture is removed by hot flue gases from the furnace (4). This is the maximum loss when efficient bag filters are employed. Further, the moisture content of the product should be 10%.

The function of this component is to heat the preprocessed feed to the desired temperature by circulating heat transfer medium and, finally, to convey the preheated material to the briquetting machine (3). During this stage, there is no material loss but some moisture is removed from the feed.

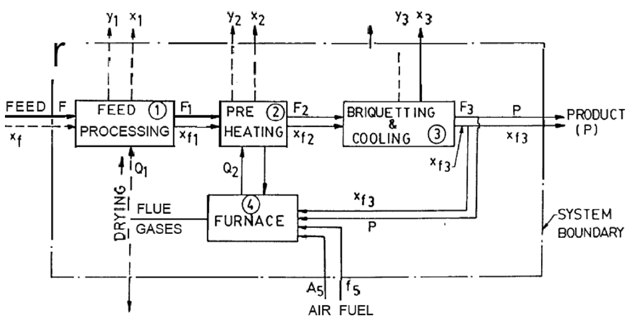

Fig. 3. An ideal briquetting plant used for conducting material and energy balance (Grover, Mishra 1996)

With reference to Fig. 3, the overall material balance is given by the following equation:

$$F - \sum_{1}^{3} X, Y - p = P \ \ (kg/h), \qquad (1)$$

where F – feed rate with xf moisture content; $X_{1,2,3}$ – moisture loss from components 1, 2 and 3; $Y_{1,2,3}$ – material loss from components 1, 2 and 3; p – the amount of briquettes used in the furnace (can be reduced to the extent of f5, extra fuel instead of a briquette); P – net production of briquettes; (xf), $(xf)_1$, $(xf)_2$, $(xf)_3$ – the moisture content of different streams on a wet basis (Grover, Mishra 1996).

Technology for Producing Fuel Briquettes

The highest prevalence of briquetting sapropel is received in the process of fuel pellets. Sapropel is a well-briquetted material without need to connect the molecules binding additives. Internal forces arising from briquettes form the mechanical strength of briquettes.

Optimal humidity for briquetting, at which provides the most low cost of its own border plant is 40–50%, but optimal humidity of sapropel is 70–85%. Ash content of the burnt briquettes does not reach more than 23% (Косов 2007; Kozlovska-Kędziora, Petraitis 2010b).

Local fuels would significantly reduce the cost of fuel imports; this is a positive answer to the environment. Public-made fuel in the common stock of fuel balance grows annually.

Biomass fuel is directly or indirectly, sub-produced from biomass. Flammable elements are carbon (C), hydrogen (H) and sulfur (S). Oxygen (O) and nitrogen (N) bind to these elements to form own internal fuel balance. Fuels also has a moisture content (M) and mineral substances which after burning becomes into ash (A).

After removal of moisture from the fuel the dry weight remains. Ashes are the product of the dry weight burning. The chemical composition of usable fuel weight can be expressed as follows:

$$C^n + H^n + S^n + O^n + N^n + A^n + M^n = 100\%. \qquad (2)$$

The chemical composition of the fuel, after removal of moisture and ash expressed as follows:

$$C^d + H^d + S^d + O^d + N^d = 100\%. \qquad (3)$$

Since the nitrogen and sulfur is a chemical compound with flammable carbon, hydrogen and sulfur elements, they are on equation of dry and combustible fuel composition by weight (Liubarskis 2006; Kozlovska-Kędziora, Petraitis 2010b).

Sawdust – Sapropel Briquettes Preparation for the Experiment

Sawdust – sapropel briquettes produced from: the furniture manufacturing waste – sawdust (moisture content to 7±1%), organic sapropel (in which the organic content to 83±2%, pH = 5.5±0.3). The unscreened sapropel sample to a moisture content of 73% was used. For the study the 10-liter tank, where the corresponding relationship mixing sawdust and sapropel was used.

Mixtures were blended in the ratio: sawdust (SW) 80% + sapropel (S) 20%.

An experiment was elected to the actual power of 25 kW domestic boiler (Viadrus U22/5). The experiments were carried out on the basis of the requirements of Lithuanian standard LST EN 303–5. Level of boiler emissions was calculated at nominal power. The composition of carbon monoxide (CO) and nitrogen oxides (NO_x), exhaust temperature and the value of oxygen (O_2) are defined for a specified period of investigation.

Composition values of carbon monoxide (CO) and nitrogen oxides (NO_x), as well as oxygen composition (O_2) in smoke and smoke temperature were being estimated in the measurement places. Hard particles and hydrocarbons were not measured. The estimations of gas products were performed by the smoke analyzer Testo- 350. Promiles (ppm) on the analyzer correspond to a thousandth part of a percent, i.e. they indicate the quantum of the material existing in the air.

Before starting the burning test of sawdust - sapropel briquettes the boiler is heated with full load of the fuel (reaching maximum filling height) till it reaches normal working conditions. The probationary period begins with the accomplishment of the obligatory heating basis.

Results and Analysis

Theoretically estimated air quantity necessary for fuel burning is not enough to start the combustion, due to the boiler's technological imperfection and insufficient commixture of fuel and air. That is to say, the amount of air supplied to the boiler is always higher than theoretically calculated amount of air.

The ratio value of air excess depends on the type of fuel, its burning manner, the boiler's design and other factors. In the process of burning one should avoid air excess because the higher the excess, the more heat is necessary for its warming. This results in lower burning temperature making the boiler less economical (Švenčianas 2003; Buinevičius, Puida 2005; Gimbutaitė, Venckus 2008).

In addition to the main combustion products eliminated during the process of fuel combustion, the amount of harmful substances, are discarded, i.e. emissions that pollute the environment. Combustion of biofuels is considered free from emissions. In fact, they do exist, but their number is much smaller than the combustion of fuel produces.

Diagrams were made for the analysis of the course of burning process presenting the results of separate burning processes during the whole period of combustion. Figs 4 and 5 presents the burning process of sawdust - sapropel briquettes and to make a comparison other authors' results.

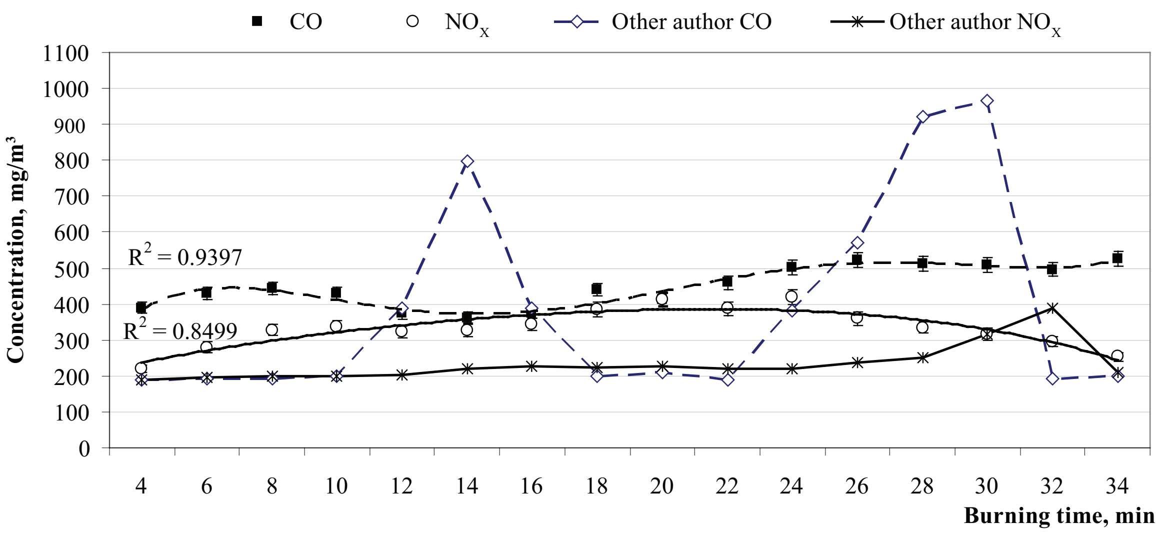

Fig. 4. CO and NO_x concentration burning the sawdust - sapropel briquettes

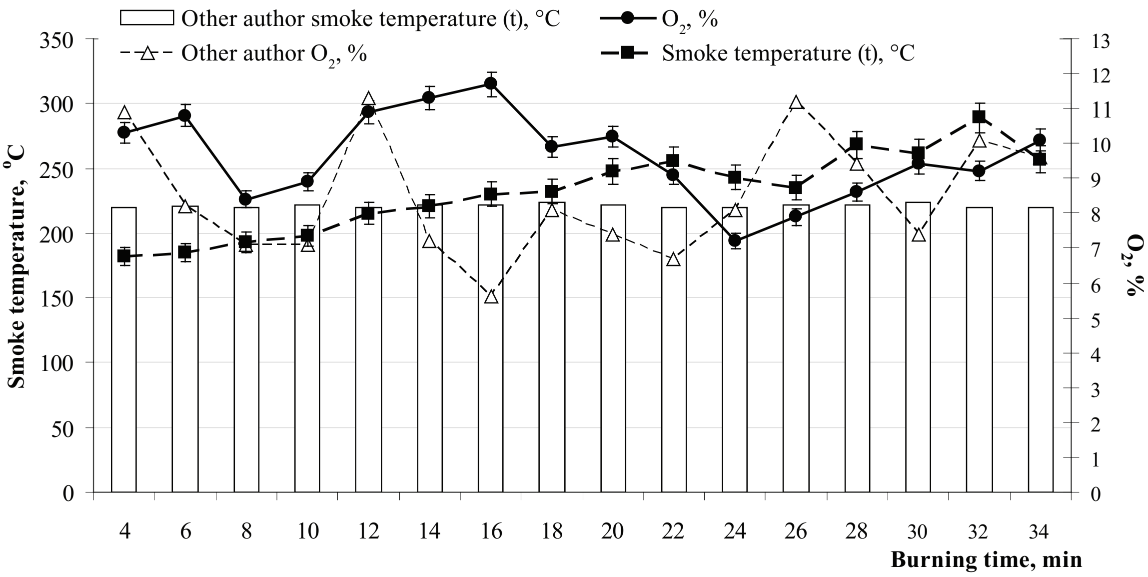

Fig. 5. Smoke temperature and oxygen concentration burning the sawdust - sapropel briquettes

In the process of ignition, the sawdust - sapropel briquettes fall from the fuel tank into the burner where they are ignited. The main element of the combustible burning mass is coal.

The composition of carbon monoxide varies from 362.02 to 526.12 mg/m^3 in the burning process of sawdust - sapropel briquettes. The largest composition of CO (526.12 mg/m^3) was fixed on the 34th minute of burning. Smoke mean temperature is 232°C.

Nitrogen, forming part of the sawdust structure, in reaction with oxygen becomes oxidized and overpasses the burning products. The composition of nitrogen oxides (NO_x) varies fractionally from 220.15 to 420.01 mg/m^3. The highest concentration of 420.01 mg/m^3 was fixed on the 24th minute of burning.

The amount of oxygen in smoke was changing from 7.2 till 11.7%. Mean oxygen concentration was 9.6%. A large surface and a sufficiently big amount of oxygen, which is provided in the form of air, are necessary for good sawdust - sapropel briquettes burning. The coal existent in the composition of sawdust reacts with the air oxygen. When sawdust - sapropel briquettes burns in insufficient amount of oxygen, the incompletely burned gas is formed, i.e. carbon monoxide.

Other authors (Gimbutaitė, Venckus 2008) show that the burning process of sawdust briquettes is very unstable. The reason is, that during the burning process of sawdust briquettes it is very difficult to control the burning process as well as the supply of air into the combustion chamber which is controlled by the primary and the secondary bolts. Because of the uneven sawdust briquettes burning process, CO smoke constitution varies at a very wide range – from 190 to 967 mg/m^3. Formation of carbon monoxide can be determined by several factors, one of them is moisture of solid fuel. Combusting moist fuel results in smoldering, therefore, more of CO is formed.

During the experiment, the authors Gimbutaitė and Venckus (2008) received that burning sawdust discharges CO 4.7 times more than granules, and 2.7 times more than briquettes. Wood briquettes discharge 15 times less CO than firewood and 2.7 times less than sawdust. Maximum CO concentration variations were established combusting firewood and lowest CO concentration variation was registered when wood granules were combusting. Therefore, to improve the sawdust's combustion it is recommended to mix it and other kinds of fuel.

This experiment shows that the sawdust mixed with sapropel improves the combustion process and reduces the emission of CO.

Discussion

The purpose of the work Afanas'ev and Misnikov (2003) is to analyze how structural changes in molded materials (peat, buried sapropel, peat–clay mixtures) during drying are affected by the concentrations of the organic and mineral matters. In this case, the interparticle interaction energy abruptly changes in the transition from one structuring step to the other, at which the phase state of the system and, consequently, the effect of interactions of various natures are different.

The analysis of the results Nikolaeva *et al.* (2009) shows that briquettes of the following compositions prepared at a compacting pressure of 150 MPa and treated at a temperature of 230ºC over 180 min possess the best mechanical characteristics:

1) 90 wt% coal + 10 wt% asphalt (Angarsk refinery);
2) 75 wt% coal + 15 wt% short residuum + 10 wt% sapropel.

On the basis of the results Nikolaeva *et al.* (2009), it has been established that the modification of petroleum residues with dried lacustrine sapropel makes it possible to prepare a binder composition for the briquetting of brown coals and to manufacture fuel briquettes with high performance characteristics.

In order to accelerate the oxidation processes and to enhance adhesive coupling in the coal–binder system, dry lacustrine sapropel was added as a structuring agent to the short residuum. Owing to its adsorption and catalytic properties and the specific structure, sapropel sorbs a part of low-molecular-mass oils and accelerate the processes of oxidation of the residuum to the bituminous state during the subsequent thermal treatment.

Extremely interesting is the work of Kosov (Косов, Беляков 2004; Косов 2007) for making fuel briquettes based on peat, which includes an introduction to the peat-modifying additives, mixing mass, pressing and drying, milled peat with a moisture content of 40–65% and grain size of 10 mm is separated first, and then it has consistently added a mixture of wood waste and coal fines, pre-impregnated with oil - diesel fuel or oil shale, then added to the mixture sapropel natural humidity 85–94%, mix and bring mixture to a moisture content of 80–85%, and then carry out a piece of molding diameter of 25–35 mm and 40–60 mm in length under pressure extruded through a die at a rate of 0.5–10 mm/s, and then carry out drying of lump fuel in two stages: the artificial with bringing to a moisture content of 35–50% at 150–200ºC and a natural with bringing to a moisture content of 25–33%, with components taken in the following percentages by weight %: wood waste in the form of sawdust – 5–10%, 10–20% of fine coal, oil or oil shale – 5–10%, sapropel natural moisture – 10–30%, milled peat and 100%.

Sapropel in the lot of a composite mixture plays the role of modifying agent colloidal structure, which upon drying increases the intermolecular interaction of components and "glue" particles. In addition, the compact aggregation leads to an increase in the intensity of drying material in 1.2–1.37 times and volume shrinkage in 1.3–1.6 times (Косов, Беляков 2004). Introduction of sapropel in the mixture in an amount of 10–30% is the optimal range. At 20% addition of sapropel density of pieces increases 1.76 times, the strength of 4.8 times.

A good burning fuel is if: fuel is exhausted, burned, smoke still minimum required for NOx, CO minimum required amount of carbon black and at least a minimum of volatile organic compounds (VOCs).

Conclusions

1. In a long time perspective of maintainable development is very important to use such energy sources as sapropel, peat etc. most effectively. It naturally should be optimized financial resources use in order to limit – if it's possible, harmful human health influences and environment. It also works for surplus creating for all parts of world population. The definite determination of typical physicalchemical properties is necessary for designing, building and checking of combusting equipments and for the thermal use of natural materials. Burning of natural recourse as sapropel is useless without meeting these premises.
2. In a medium time perspective greenhouse gases emissions produced by human activities are influencing climatic changes. These should be set by acceptable methods. An impact of short time effect to energy supply for example is inconsiderable. Support of the natural non food production for its use such as slow renewable energy source is considered as a perspective way not only in the meaning of ecology aspect.
3. In general in spite of the problems that arise during the process, the herbaceous and other materials used in the experiments can be briquetted and used as fuel. All technical and technological problems can be solved.

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SAPROPELIO PANAUDOJIMO GALIMYBĖS BRIKETAMS GAMINTI

J. Kozlovska-Kędziora, E. Petraitis

Santrauka

Straipsnyje pateiktos atsinaujinančių energijos kuro šaltinių panaudojimo galimybės šilumos energijai gaminti.
Viena iš galimybių (alternatyvų) yra sapropelį (ežerų dugno nuosėdų biomasę) naudoti ne tik kaip trąšą, pašarų priedą, rišiklį ir pan., bet ir kaip energetinį elementą. Straipsnyje pateikta: žaliavos paruošimas kuro briketams gaminti, paruoštos biomasės briketavimo technologija, pagamintų sapropelio su priedais briketų deginimas (tiesiogiai naudojamų šilumai išgauti), briketus deginant išsiskiriančių teršalų koncentracijos. Gauti rezultatai lyginami su kitų autorių analitiniais ir eksperimentiniais rezultatais.

Reikšminiai žodžiai: sapropelis, briketai, briketų gamyba, CO, NO_X.