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Sapropel use as a Biofuel Feasibility Studies

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Abstract

Renewable energy sources are of great significance in addressing the problems of energy resources, not only now but in the future. The resources of fossil fuel in Lithuania are very limited. Since fossil fuel resources are rapidly diminishing, there is a global focus on renewable energy sources and developing new energy-saving technologies. The use of energy sources such as sapropel (sludge lakes), not only require less imported fossil fuels, but also dealt with a very topical issue of environmental pollution. It was found that the use of briquettes consisting of sapropel can help save other energy resources. The combustion process of such briquettes is longer than conventional briquettes as sapropel samples reduce shrinkage and intensify the combustion process. Because of its good physical and chemical properties sapropel can be mixed with other types of biofuels such as straw, sawdust or peat. This study has found the calorific value of sapropel and its mixtures and the measured concentrations of gaseous pollutants sapropel briquettes during combustion. Manufactured briquettes (sapropel - straw, sapropel – peat, sapropel - sawdust) were combusted in a residential boiler and in the combustion process the concentrations of gaseous pollutants were measured. It was determined that the sapropel and biofuel addictives briquettes can be burned, and the concentration of pollutants at the combustion process does not exceed the normative limits.

Keywords: sapropel, briquetted, caloric value, combustion, emission.

Introduction

Carbon dioxide (CO_2), as well as noxious carbon monoxide-carbon (CO), nitrogen oxides (NOx) and many other compounds are inevitably exuded during each burning process. On the contrary, use of biomass for heating has a far less effect on the environment than the use of mined fuel[1,2]. Biomass briquettes may well be the energy source of the future for many countries. They can reduce pollution, improve health, and provide a steady source of fuel. They can preserve the forests of countries all over the globe. Using biomass briquettes as a renewable energy source is a good choice for energetics.

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.

Briquetting is a process in which a material with appropriate characteristics is subjected to high pressure, time and high temperature. Increased temperature in cellulosic materials (wood, straw, etc.) causes the particles of the material plastically. After eliminating the pressure a material retains new features (shape, specific gravity, mechanical properties). The briquetting process is widely used in industry. There are many uses for press briquettes, including fine coal and lignite, peat, sapropel, sawdust etc. [3, 4].

Biomass burning releases trace gases and aerosols, which play a significant role in atmospheric chemistry. These contribute significantly to the uncertainty in climate change and affect both local and global air quality which impacts human health and environment. The emissions released from biomass burning, therefore, have recently emerged as an important research topic. In the last decade, biomass burning studies have spawned hundreds of manuscripts on the physical, chemical, and thermodynamic properties of biomass burning particles [4–7].

Material and Methods

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: i. moisture content should fluctuate within a 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; ii. an appropriate fraction – the briquetting process runs smoothly due to larger surface adhesion molecules bonded in the briquette; iii. the material type for briquette, its density, the ability to bond under the influence of particular pressure and temperature; iv. 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.

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. Sapropel is formed as a result of biochemical, microbiologic and physical-mechanical processes. It is a complex matter of organic and mineral origin and it mostly consists of the remains of plankton, benthos, algae and other hydrophytes that have stratified with particles of sand, clay and limestone. Colloidal structure of sapropel allows it to achieve the properties of natural sorbent after the removal of free water. The organic component of the sapropel (~75%) determines such important properties as the biological activity, biochemical stability, adhesive ability, but it acts as a catalyst for the oxidation of heavy tar on the border of the coal binder that allows you to get the final product – the briquette with the required physical and mechanical properties [7–9]. As for its origin, sapropel may be organic or mineral–carbonaceous with pH 6.0–7.5. Its dry matter may include 79.8–90.8 % of organic substances, 2.27–3.56 % of nitrogen, 0.56–1.18 % of calcium, 0.9–0.15 % of P_2O_5, and 0.055–0.2 % of K_2O. Sapropel may include microelements and metals, the organic part is rich in biologically active substances and vitamins [10–15].

Optimal humidity for briquetting, at which it provides the lowest 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% [3, 16].

The mixtures for the experiment were blended in the ratio in table 1: sapropel (S) + additive (peat (P) or sawdust (SW) or straw (ST)). The experimental technology of making briquettes presented in figure 1.

Table-1
The composition of produced briquettes

Components	Peat (P), %	Sawdust (SW), %	Straw (ST), %
Sapropel (S), %	50:50	50:50	50:50
	60:40	60:40	60:40
	70:30	70:30	70:30

Fuel briquettes have various shapes and sizes, depending on manufacturing technologies. Briquette production process consists of many operations depending on individual characteristics of the extruded material.

Combustion of biomass briquettes with sapropel and gas emissions estimation: For the experiment the domestic boiler (Viadrus U22/5) with the actual power of 25 kW was elected. The experiments were carried out on the basis of the requirements of Lithuanian standard LST EN 303–5. The level of boiler emissions was calculated at nominal power. The composition of carbon monoxide (CO) and nitrogen oxides (NOx), 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 (NOx), 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 350XL. 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 sapropel briquettes the boiler is heated with full load of the fuel (reaching maximum filling height) until it reaches normal operating conditions. The probationary period begins with the accomplishment of the obligatory heating basis.

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 internal fuel balance. Fuels also have a moisture content (M) and mineral substances which become ash (A) after burning. After removing the 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:

$$C_n + H_n + S_n + O_n + N_n + A_n + M_n = 100\% \quad (1)$$

Figure-1
Technology for producing sapropel and sawdust briquettes

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

$$C_d + H_d + S_d + O_d + N_d = 100\% \cdot \quad (2)$$

Since the nitrogen and sulfur are chemical compounds consisting of flammable carbon, hydrogen and sulfur elements, they are on equation of dry and combustible fuel composition by weight[3,17].

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 [1,3,18].

In addition to the main combustion products eliminated during the process of fuel combustion, the amount of harmful substances, i.e. emissions that pollute the environment, is reduced. Combustion of biofuels is considered to be free from emissions. In fact, they do exist, but their number is much smaller than the combustion of fuel produces. Figure 2 presents the burning process composition of carbon monoxide (CO) and nitrogen oxides (NOx).

The composition of carbon monoxide varies from 248.0 to 539.0 mg/m^3 in the burning process of organic sapropel and additives briquettes. The maximum CO concentrations measured in the sapropel (50%) – peat (50%) briquettes combustion, which were 539.0 mg/m^3. The maximum NOx concentrations measured in the sapropel (50%) – straw (50%) briquettes combustion, which were 314.0 mg/m^3. The lowest NOx concentration of 144.0 mg/m^3 was measured in the sapropel (70%) – peat (30%) briquettes combustion. The sapropel and additives briquette during combustion NOx concentrations varies from 144.0 to 270.0 mg/m^3.

The measurement results show that none of the concentrations of briquettes combustion exceed the standard requirements [19].

Results and Discussion

For caloric values of different biomass briquettes with sapropel estimation several experiments were executed in VGTU (Vilnius Gediminas Technical University) and LEI (Lithuanian Energy Institute) using different components of briquettes, including sapropel, peat, sawdust and straw. The lower calorific value of the aforementioned components was measured with calorimeter IKA C5000 showed in figure 3. IKA C5000 oxygen bomb calorimeters are leading in determining the calorific values of liquid and solid samples. The selection of IKA oxygen bomb calorimeters is optimally geared towards various different demands. A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion in a particular reaction. Bomb calorimeters have to withstand the large pressure and force of the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel, as the fuel is burning, it heats up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it also heats up the water outside the tube. The temperature of the water allows to calculate the calorie content of the fuel [2, 6].

Mixtures of the lower calorific value determined by the formula 3:

$$Q_{MC} = S_C \cdot Q_{SC} + A \cdot Q_{AC} \quad (3)$$

were:

$$S_C + A = 100\% \quad (4)$$

where: Q_{MC} – a mixture calorific value, MJ/kg, S_C – sapropel content,%, Q_{SC} – organic sapropel calorific value, MJ/kg (20.6 MJ/kg), A – additives (peat, sawdust, straw) content,%; Q_{AC} – additive the calorific value, MJ/kg (peat – 22.0 MJ/kg, sawdust – 14.5 MJ/kg, straw – 15.0 MJ/kg).
Figure 4 shows calculated the lower calorific values of organic sapropel with additives.

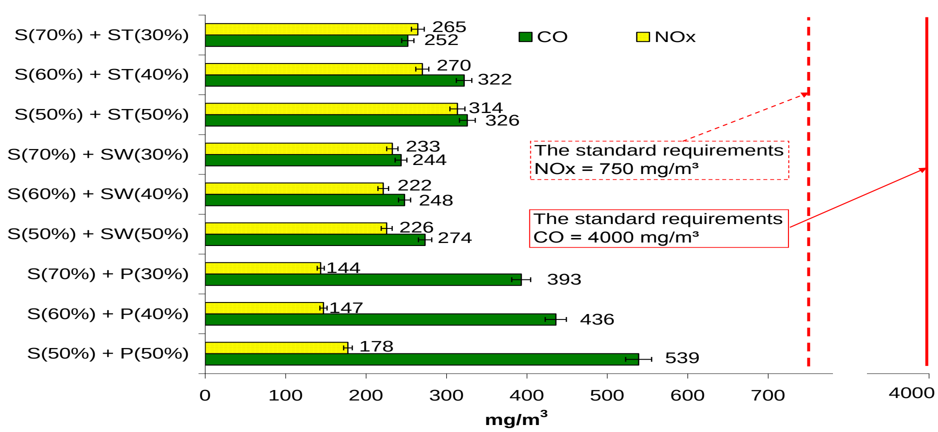

Figure-2
The burning briquettes concentration CO and NOx (S – sapropel, ST – straw, SW – sawdust, P – peat)

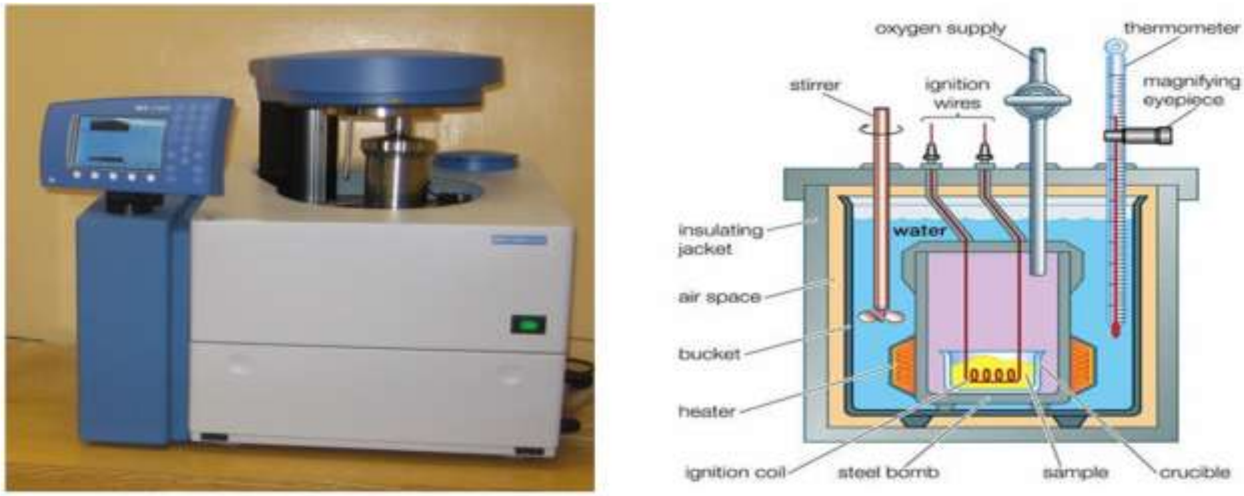

Figure-3
Calorimeter IKA C5000

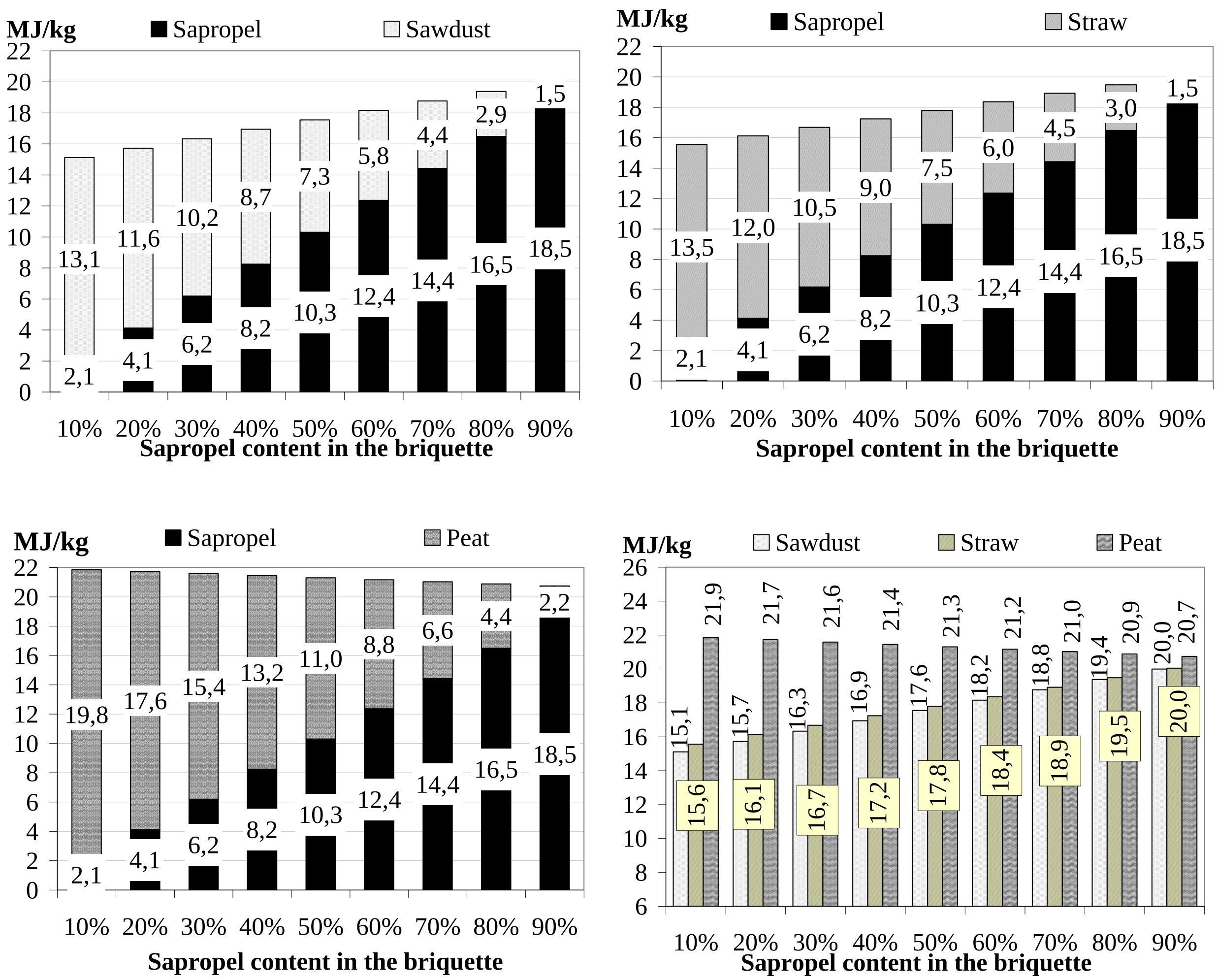

Figure-4
Sapropel briquettes lower calorific value

Sapropel has a lot of organic matter. The analysis of calorific value showed that organic sapropel is suitable for the production of biofuel briquettes, since the result is 20.6 MJ/kg.

The analytical results in figure 4 showed that the highest energy value can be achieved by mixing sapropel with peat (respectively sapropel 10% and peat 90%, the calorific value is 21.9 MJ/kg). However, such combination of biofuels is not effective, because increasing the amount of sapropel in briquettes from 10% to 90% reduces the calorific value of the mixture. In addition, sapropel is not necessary as a binding agent for peat briquettes.

The opposite situation is a mixture of sapropel with straw and sawdust, which is required the binder, and sapropel can serve for it. Most importantly, the increased level of sapropel in biofuels briquettes increases their energy value. When the amount of sapropel is increased from 10% to 90% in briquettes consisting sawdust or straw, the calorific value of a briquette increases from 15.1 MJ/kg to 20.0 MJ/kg.

Studies of sapropel's use as a binder showed that the compressive strength of the samples increases with increasing content of sapropel in briquettes, but the use of sapropel more than 50% of the sample has poor adhesion due to the high moisture content and is not strong enough, in addition to a large amount of sapropel is difficult briquette kindling[20, 21].

Conclusion

Extracted lake sapropel can be used for the different types of biofuel briquettes produce, especially since creating renewable and local energy sources (biofuels from biomass) and using them is one production and use is one of the major European Union energy strategy objectives.

The studies have shown that mixing sapropel with peat is inefficient, because sapropel reduces briquette calorific value, and in addition it is not necessary as a binding agent. Meanwhile, for a mixture of sapropel with sawdust and straw, it is not only a binder but also increases the energy value of the briquettes.

Considering that the recommended amount of sapropel for the production of biofuel briquettes is up to 50%, mixing equal parts of sapropel and sawdust or straw, the calorific value of such briquettes is 17.6 MJ/kg and 17.8 MJ/kg.

Environmental study of biofuel briquettes with sapropel showed that the gas emissions values from the combustion process do not exceed the normative limits and this kind of biofuel can be used as a renewable energy source.

References

1. Gimbutaitė I. and Venckus Z., Air Pollution Burning Different Kinds of Wood in Small Power Boilers, *J. Environ. Eng. Landsc.*, **16(2),** 97–103 **(2008)**

2. Okoro L.N., Belaboh S.V., Edoye N.R., Makama B.Y., Synthesis, Calorimetric and Viscometric Study of Groundnut oil Biodiesel and Blends, *Res. J. Chem. Sci.*, **1(3),** 49–57 **(2011)**

3. Kozlovska – Kędziora J. and Petraitis E., The Possibilities of Using Sapropel for Briquette Production, *Science – Future of Lithuania*, **3(5),** 24–30 **(2011)**

4. Reid J.S., Koppmann R., Eck T.F. and Eleuterio D.P.A review of biomass burning emissions part II: intensive physical properties of biomass burning particles, *Atmos. Chem. Phys*., **5,** 799–825 **(2005)**

5. Branc M., Horák J. and Ochodek T. Fine particle emissions from combustion of wood and lignite in small furnaces, *Environ. Prot. Eng*., **2,** 123–132 **(2011)**

6. Okoro L.N., Sambo F.I., Lawal M. and Nwaeburu C., Thermodynamic and Viscometric Evaluation of Biodiesel and Blends from Olive Oil and Cashew Nut Oil, *Res. J. Chem. Sci*., **1(4),** 90–97, **(2011)**

7. Lewandowski W.M., Radziemska E., Ryms M. and Ostrowski P. Modern methods of thermochemical biomass conversion into gas, liquid and solid fuels, *Ecol. Chem. Eng. S*., **18(1),** 39–47 **(2011)**

8. Menzell K., Mirzaev S.Z. and Kaatzell U. Crossover behaviour in micellar solutions with lower critical demixing point: Broadband ultrasonic spectrometry of the isobutoxyethanol-water system, *Phys. Rev. E*, **68,** 73–84 **(2003)**

9. Petrova L.A., Latishev V.G. and Burenina O.N. Poluchenije bitovyh toplivnyh briketov s ispolzovanijem neftjanych svjazujushcih, *Neft. Del. UDK* **1,** 662–678 **(2007)**

10. Iorfa A. Ch., Ntonzi N.T., Ukwang E.E., Abara IBE K. and Neji P., A Study of the Distribution pattern of Heavy metals in surface soils around Arufu Pb-Zn mine, Northeastern Nigeria, Using Factor Analysis, Res. J. Chem. Sci., **1(2),** 70–80 **(2011)**

11. Katkevičius L., Ciūnys A. and Bakšienė E. Sapropel from Lakes for Agriculture. LŽI, Dotnuva, 94 **(1998)**

12. Ajorlo M., Abdullah R.B., Hanif A.H.M., Halim R. Abd. and Yusoff M.K., How Cattle Grazing Influences Heavy Metal Concentrations in Tropical Pasture Soils, *Pol. J. Environ. Stud.* **19(6),** 1369–1375 **(2010)**

13. Sangeeta D. and Savita D., Hydro chemical changes in two eutrophic lakes of Central India after immersion of Durga and Ganesh idol, *Res. J. Chem. Sci.*, **1(1),** 38–45 **(2011)**

14. Vaishnav M.M. and Dewangan S., Assessment of Water Quality Status in Reference to Statistical Parameters in Different Aquifers of Balco Industrial Area, Korba, C.G. INDIA, *Res. J. Chem. Sci.*, **1(9),** 67–72 **(2011)**

15. Butkus D. and Šalčiunienė K., Investigation of heavy metal and radionuclide distribution in silt of Lake Didžiulis, *J. Environ. Eng. Landsc.*, **19(3),** 215–224 **(2011)**

16. Kosov V.I. Sapropel. Resursy, technologij, geoekologija. Nauka, Sankt – Peterburg, 225 **(2007)**

17. Liubarskis V. Biofuel for furnaces. Milga, Raudondvaris, 44 **(2006)**

18. Buinevičius K. and Puida E. Reduction of NO_X concentrations in boiler flue gas by injecting selective reagents, *J. Environ. Eng. Landsc.*, **13(2),** 91–96 **(2005)**

19. LAND 28-98/M-08. Stacionarūs atmosferos teršalų šaltiniai. Dujų srauto ir tūrio debito ortakyje matavimas [Stationary sources of air pollution. The gas rate and volume flow measurements in the duct], Vilnius LR AM, 38 **(1998)**

20. Bieliauskas N. Termoizoliacinių plokščių iš pjuvenų ir sapropelio gamybos tyrimai [Research of briguettes production of sawdust and sapropel], LŽŪU, 45 **(2007)**

21. Germanavičius G. Termoizoliacinių plokščių su sapropelio rišikliu ir šiaudais tyrimai [Research of briquettes with sapropel binder and straw], LŽŪU, 64 **(2009)**