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CALORIFIC VALUE OF HOUSEHOLD WASTE AND PEAT FROM THE POLTAVA REGION

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Abstract. This paper presents the results of an experimental study on the calorific value of municipal solid waste and peat. The analysis of the heat of combustion of combustible fractions of municipal solid waste was conducted based on the morphological composition of waste generated in the settlement of Kotelva, Poltava region, Ukraine. The calorific values were determined using actual measurements obtained through laboratory testing with a bomb calorimeter. Based on the acquired data, formulas for calculating both the higher heating value (HHV) and lower heating value (LHV) were derived. The analysis of the energy potential of combustible fractions of municipal solid waste and peat indicates a high capacity for thermal energy generation. The study concludes that developing composite fuel mixtures from high-calorific waste fractions and peat is both feasible and energy-efficient.

Keywords: calorific value, municipal solid waste, combustible fractions, peat, composite fuel mixture, moisture.

1. Introduction

Currently, the impact and consequences of military actions necessitate the search for alternative, more efficient and autonomous sources of heat and energy supply, including the development of new types of fuels, especially for decentralized small-scale municipal energy systems. According to the Law of Ukraine No. 2320-IX "On Waste Management" dated June 20, 2022 (Law of Ukraine No. 2320-IX, 2022), the following principles of waste management are defined: waste prevention; preparation for reuse; recycling; waste recovery (including energy recovery); and final disposal. The proportion of waste currently being sorted is extremely low, as only certain materials with market value are separated – such as paper, plastic bottles, glass cullet, and scrap metal. One of the methods of handling municipal solid waste (hereinafter referred to as MSW) is the thermal treatment of its combustible fractions.

A significant advantage of using MSW as an energy source lies in its continuously rising quantity and its convenient location, within populated areas, in close proximity to energy consumers. For many years, leading countries throughout the world have considered MSW to be a growing alternative energy source capable of partially replacing natural gas for the production of thermal and electrical energy by converting district heating plants or boiler houses to waste-derived fuels.

Among the non-traditional solid fuels known in Ukraine, increasing attention is being paid to peat (Saranchuk et al., 2008; Sniezhkin & Korinchuk, 2022). A review of the scientific literature (Geogroup, 2024) indicates that there are considerable peat reserves in the Poltava region. In turn, many countries around the world have long understood the economic efficiency of using peat as fuel.

For example, peat accounts for up to 10–15 % of the fuel balance in Northern European countries. Finland holds the record, with peat accountting for a quarter of its fuel balance. In Ukraine's fuel balance, peat accounts for only about 0.3 % (Geogroup, 2024). This paper highlights the issue of using peat as an element of a fuel composite mixture with combustible fractions of household waste, which is confirmed by scientific novelty.

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Therefore, this study aims to determine the combustion heat of combustible fractions in municipal solid waste and peat from local deposits in the Poltava region to assess their potential as raw materials for small-scale energy generation and/or the partial substitution of conventional energy resources with alternative fuels.

2. Experimental part

The significant increase in the generation and accumulation of municipal solid waste (MSW) in the Poltava region leads to a corresponding growth in the number of landfills, including illegal dumping sites. This, in turn, results in extensive land contamination and elevated emissions of pollutants into various environmental compartments. Moreover, the disposal of MSW in landfills causes the loss of potentially substantial quantities of resource-rich materials that could serve as secondary raw materials, thereby substituting conventional non-renewable natural resources (Illyash & Holik, 2023).

Within the framework of a research project conducted under bilateral international scientific cooperation with the Republic of Austria on the topic “Study of the Composition and Resource Potential of Municipal Solid Waste” (Final report on the results of research work, 2024), a series of original sorting analyses of municipal solid waste (MSW) were planned and carried out in the Kotelva community, Poltava region, Ukraine, during the period 2023–2024. The rationale for selecting this community as the subject of the morphological composition study of MSW is described in (Final report on the results of research work, 2024). Sorting analyses were performed following the methodological recommendations of Ukraine (The Supreme Council of Ukraine Order, 2010; Order Ministry of Development of Communities, Territories and Infrastructure of Ukraine, 2024) as well as selected provisions of European methodologies, namely the “Guidelines for conducting residual waste sorting analyses” and the SWA-Tool (Guidelines for conducting residual waste sorting analyses, 2021; SWA-Tool, 2024). In this article, the results regarding the component composition of MSW are based on those obtained according to the Ukrainian methodology (The Supreme Council of Ukraine Order, 2010; Order Ministry of Development of Communities, Territories and Infrastructure of Ukraine, 2024). To understand the composition of only the combustible fractions within the overall sample, a recalculation was performed to determine the share of resource-recoverable components characteristic of each season during the study period (Table 1).

Table 1

Summary of the Component Composition Analysis of Municipal Solid Waste

	Percentage composition in Total Mass of Combustible Fractions, %			
	Paper and Cardboard	Plastic materials (plastics and other polymers)	Textiles	Wood
Autumn	22.42	58.82	8.02	1.5
Winter	13.85	41.57	15.0	1
Spring	32.0	64.3	4.0	0.5
Summer	28.97	36.77	11.26	0,5

In the course of this study, a combination of methods was applied, including systematization, generalization, and qualitative assessment of the obtained experimental data.

The determination of the heat of combustion of a fuel is one of the main methods for assessing its energy value. This parameter can be established by two principal methods: experimental and theoretical (calculation-based). The experimental approach involves combusting a sample of the fuel under study – municipal solid waste (MSW) and peat – in an oxygen-rich environment inside a sealed metal vessel (a bomb calorimeter) submerged in water. During combustion, the entire amount of heat released is absorbed by the surrounding water and subsequently measured. By knowing the mass of water and the change in its temperature, the heat of combustion can be calculated (Sklyarenko et al., 2023).

In this study, the heat of combustion of the fuel was experimentally determined using a bomb calorimeter (Fig. 1). The primary function of a calorimeter is to measure the amount of thermal energy released or absorbed during chemical reactions, particularly combustion processes.

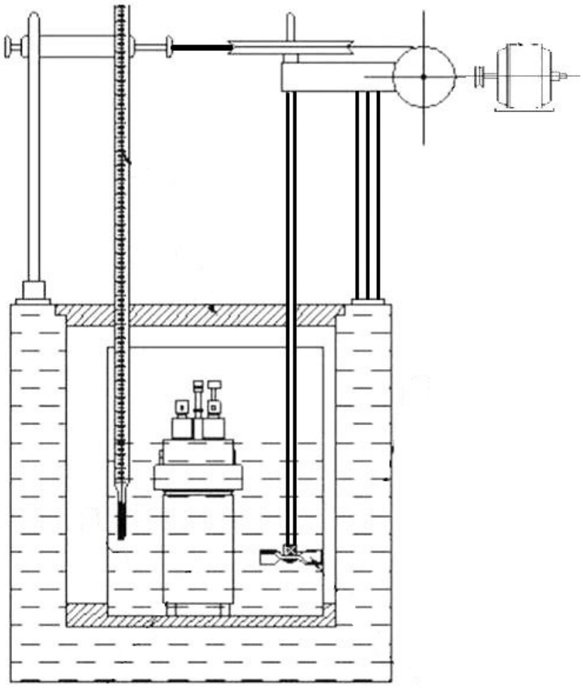

Fig. 1. Calorimeter for Determining the Calorific Value of Fuel

To determine the calorific value of the combustible fractions of municipal solid waste and peat, research samples were prepared.

This stage is crucial, as the calorific value of municipal solid waste and peat is a key parameter that defines their efficiency as a thermal energy source. The samples of combustible materials were carefully selected and prepared for the analysis. The pressing process allowed the creation of standardized samples (Fig. 2), consisting of three "pellets" of each type of waste and peat, to reduce measurement errors. Each pellet contained a copper wire used to ignite the tested sample inside the bomb calorimeter crucible.

Fig. 2. Tested samples with copper wire

The weight of each "pellet" with the copper wire was approximately 1 g ± 0.1 g.

Using a calorimeter, the calorific value of each analyzed sample of municipal solid waste (MSW), classified according to its morphological composition, as well as peat from the Poltava region deposits, was determined. Based on the obtained data, the higher and lower heating values (HHV and LHV) were calculated using the following formulas:

Higher Heating Value (HHV):

$$Q_{HHV} = ((Q + \Delta Q_{loss}) - qCu)/\, m_{pellet}/1000/1000,\ \text{MJ/kg}, \quad (1)$$

where Q is the amount of heat released during water heating, J; ΔQ_{loss} is the heat losses to the environment, J; qCu is the amount of heat released during the combustion of copper, J; m_{pellet} is the mass of the test sample pellet (excluding the mass of the copper wire), g.

$$\Delta Q_{loss} = A \times (\Delta t_0 + (t_{i-1} + t_i)/2) \times \Delta Z_i, \text{ J}, \quad (2)$$

where A is the heat loss coefficient of the calorimeter, W/°C; Δt_0 is the baseline temperature difference, °C; t_i is the temperature during a specific time interval, °C; ΔZ_i is the time increment (time change), s.

The baseline temperature difference is defined by the formula:

$$\Delta t_0 = t_{0Beckman} - t_{ambient}, \text{ °C}, \quad (3)$$

where $t_{0Beckman}$ is the "zero point" temperature of the Beckman thermometer, °C; $t_{ambient}$ is the ambient temperature, °C.

$$qCu = (\Delta H/M_{Cu}) \times m_{wire}, \text{ J}, \quad (4)$$

where ΔH is the heat of combustion of crystalline copper, equal to 162.000 J/mol; M_{Cu} is the molar mass of copper, equal to 63.55 g/mol; m_{wire} is the mass of the copper wire, g.

Lower Heating Value (LHV):

$$Q_{LHV} = ((Q + \Delta Q_{loss}) - qCu) - Q_{vap} \times \times 1000)/ m_{pellet}/1000/1000, \text{ MJ/kg}, \quad (5)$$

where Q is the amount of heat released during water heating, J; ΔQ_i is the heat losses to the environment, J; qCu is the amount of heat released by copper, kJ; Q_{vap} is the heat of condensation of water vapor, kJ; m_{pellet} is the mass of the tested sample pellet, g.

$$Q_{vap} = m_{cond} \times q_{cond}/1000, \text{ kJ}, \quad (6)$$

where m_{cond} is the mass of condensed water vapor, g; q_{cond} is the heat of condensation of water vapor, kJ/kg, equal to 1891 kJ/kg.

For data analysis and processing, Microsoft Excel software was used. Table 2 presents the results of the lower heating value calculations, derived from the higher heating value estimations.

Table 2

Lower Heating Value of Tested Samples

Fuel Type	Heating Value, MJ/kg
Paper & Cardboard (50:50)	14.601
Glossy Paper	*8.872*
Plastic:	
– *Polypropylene (PP)*	*34.582*
– Low-Density Polyethylene (LDPE)*	34.352
Textile	13.249
Wood:	
– Ash	15.963
– Pine	18.084
Peat	14.301

Note: LDPE* – low-density polyethylene.

Table 2 shows that the average heating value ranges from 8.872 MJ/kg (glossy paper) to 34.582 MJ/kg (plastic – polypropylene), depending on the specific type of the studied component.

3. Results and Discussion

When characterizing each studied component, it is important to note that glossy paper exhibits the lowest heat of combustion. The study revealed that this component not only has a low calorific value but also a high ash content, which is caused by a significant proportion of non-combustible mineral substances. Therefore, it is advisable not to use this component of municipal solid waste as fuel. From this, it follows that the thermal value of waste is directly proportional to its carbon content and inversely proportional to its ash content and moisture level.

Regarding wood (ash and pine), pine is recommended as a fuel component because it releases higher heat (18.084 MJ/kg) compared to ash (15.963 MJ/kg) and exhibits binding properties due to its structural characteristics.

The experimental work studied two types of plastics: polypropylene and low-density high-density polyethylene, which are the most common in the morphological composition of municipal solid waste from settlements. The results show that polypropylene yields the highest heat of combustion (34.582 MJ/kg).

The development of composite fuel mixtures based on peat combined with household waste is critical for improving energy efficiency and replacing imported energy sources. It allows for the optimization of moisture content, increased fuel energy density, and reduced emissions of harmful substances, ensuring the economical use of local resources. It is advisable to use those fractions of household waste that have the highest calorific value as fuel components, i.e., classic biogenic materials: paper and cardboard and wood (to improve the combustion process) and polypropylene and textiles (mixed).

4. Conclusions

The conducted research indicates the feasibility and prospects of developing a composite fuel blend based on the combustible fractions of municipal solid waste (MSW) and peat. This blend is characterized by a high calorific value due to the presence of high-energy MSW fractions and a low emission profile owing to peat's adsorptive properties. The development and combustion of such composite fuel blends will contribute to minimizing the environmental impact of combustible MSW fractions while providing an effective source of thermal energy.

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