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Study of emissions into the atmosphere from the combustion of pellets and solid waste

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Abstract. The problem of waste is becoming increasingly urgent as the volume of waste and its negative impact on the environment grow. Thermal treatment is one of the most effective methods of reducing the volume of waste, but it also results in the release of pollutants into the atmosphere. Therefore, the study of air emissions from the incineration of different types of waste, as well as pellets made from different types of wood, was the aim of this research. During the visit to the solid waste landfill in Rybne village, waste samples were collected for further research. A comparative analysis of the level of emissions into the atmosphere of a mixture of waste corresponding to the morphological composition of the solid waste landfill in Rybne village was carried out. A comparative analysis was also carried out for the level of air emissions and calorific value of each type of waste, pellets and their mixtures. The study showed that the level of pollutant emissions into the atmospheric air depends on the type of waste and the technology of its incineration. The highest pollutant emissions are observed during the incineration of plastic, rubber and bio-waste. Solid fuels such as wood, paper and textiles emit fewer pollutants. A graph comparing the calorific value of different types of waste and pellets with the levels of air emissions has been developed. The graph shows that, as a rule, the higher the calorific value of the fuel, the lower the levels of pollutant emissions. The results of the study are valuable in practice for improving the methods of household waste utilisation for heat production, in particular, for selecting fuel compositions that minimise the levels of the studied pollutants in the air

Keywords: solid household waste; thermal disposal; caloric content; emissions into air; solid particles

Introduction

Solid household waste is one of the biggest problems faced by modern society. Billions of tonnes of municipal solid waste (MSW) are generated worldwide every year and this figure is growing. Solid waste (SW) consists of a wide variety of materials, including plastic, paper, textiles, metal, glass and food waste. MSW continues to grow and poses a significant challenge to local governments, most of which do not keep records of waste generation, sources and characteristics. This lack of information means that decisions on appropriate waste management are based on assumptions

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and guesswork, leading to mismanagement with serious environmental consequences. Examples include contamination of rivers and groundwater by landfill leachate, soil contamination, greenhouse gas emissions and animal mortality. One way to reduce the amount of waste is to convert it into fuel. Solid household waste and solid fuel pellets are a source of energy, but during thermal disposal they also release chemical compounds into the air that can be harmful to human health and the environment.

Studies like A. Kaur *et al.* (2023) show that MSW production will increase from 1.3 billion tons in 2012 to over 2.2 billion tons per year in 2025. This poses serious environmental and sanitary problems due to a lack of disposal sites. The use of MSW as an energy source is gaining popularity due to waste-to-energy technologies. These technologies, including gasification, pyrolysis, and incineration, convert waste into synthetic gas, which is then used to generate electricity. Another paper, by O. Bulyandra *et al.* (2020) focuses on the development of MSW fuel formulations to minimize emissions, demonstrating the potential of this approach. This article complements studies by examining the impact of waste type and wood pellets on emissions and calorific value, offering practical recommendations for improving MSW utilization methods for heat production. Existing research actively explores techniques to minimize the environmental impact of waste disposal. One such study by G. Wong *et al.* (2020) investigated the co-processing of fly ash and bottom slag from MSW incineration through low-temperature melting. This approach aimed to reduce energy consumption and potential leaching toxicity of the resulting slag, demonstrating the potential for innovative solutions in waste management.

In recent years, many countries have shown interest in new environmentally safe and waste-free technologies for the thermal processing of household waste with the formation of combustible gases. These technologies make it possible to obtain energy from solid household waste without releasing pollutants into the atmosphere. In Ukraine, there is a national waste management program, which defines the main directions of the development of the waste management system in Ukraine until 2030 (Resolution of the Cabinet of Ministers of Ukraine No. 117-p, 2019). According to the program, by 2030, the level of solid household waste processing in Ukraine should be at least 50%.

Authors P. Pysarenko *et al.* (2022) studied the impact of landfills on the environment and D. Tokarchuk *et al.* (2023) investigated the possibility of secondary use. The principles laid down in their works formed the basis of presented research. While there are studies on the impact of different Waste-to-Energy technologies on pollutant emissions, there is a lack of information on emissions from different types of waste and fuel pellets. This article focuses on filling this gap. The purpose of the work was to determine the level of emissions of pollutants into the atmospheric air and emissions of solid particles during the burning of waste, according to their different types, as well as solid fuel pellets, to compare the amount of thermal energy with the level of emissions into the atmospheric air.

Materials and Methods

The following methods were used to achieve the aim of the study. Sampling of MSW was carried out in the spring and summer of 2023 on the territory of the "Municipal solid waste landfill" of Rybne village, Ivano-Frankivsk territorial community, Ukraine. Combustible types of waste were selected for the experimental samples, such as: paper, plastic, rubber, textile, wood, bio-waste and unsorted combustible residues, as well as a combined mixture of waste, which corresponds to the morphological composition of the waste of the "Municipal solid waste landfill" of Rybne village. Reference samples of solid fuel wood pellets were selected: oak, pine needles 30%, beech 30%, oak 40%, pine needles 50%, beech 30%, oak 20%, Jerusalem artichoke, pine needles, beech. Their mixture was taken into account in the research.

The method of researching the moisture content in experimental samples of solid household waste and reference solid fuel pellets was used. It is based on drying a weight of fuel in a drying cabinet at a temperature of (140 ± 50˚C) and calculating the mass loss. The selection of fuel weights from the analytical sample was carried out in the same way as in the main method of determination, that is, from two or three places of a thoroughly mixed analytical sample. Weight of the fuel gauge (5 ± 0.1 g). The drying cabinet was heated to 140...145˚C with the ventilation flaps open. The glasses, with weights, were placed on the cabinet shelf in such a way that part of the shelf openings remained open. The drying time was 20-30 minutes. Determination of moisture content was calculated using the formula:

$$A^a = \frac{m_3 - m_1}{m_2 - m_1} \cdot 100\%, \quad (1)$$

where m_1 is the mass of the crucible; m_2 is the mass with the weight of the fuel sample; m_3 is the mass of the crucible after drying with fuel, g. From the selected and appropriately prepared samples of solid household waste and solid fuel wood pellets, a fuel sample was formed using a press. The mass of the formed sample tablet corresponded to 1 g ± 0.05. The sample was placed in a crucible, which was installed in the holder of the calorimetric cover-bomb, 1 ml of distilled water was introduced into the bomb and placed in the calorimeter to conduct an experiment to determine the heat of combustion.

With the help of a NEUS solid fuel boiler (Noteus LLC, Ukraine), the process of burning test samples was carried out. The process of obtaining data on the levels of harmful substances was carried out according to the method of measuring pollutant emissions from stationary emission sources. Emissions were measured directly in the centre of chimney diameter, not less than a distance of two diameters from the last bend using a measuring probe. The levels of pollutant emissions into the air were measured by the gas analyser OKSI 5M (ECOTEST LTD, Ukraine) and the air quality analyser CEM DT-9881 (CEM Instruments, China). Meteorological characteristics were measured at the level of human breathing (about 2 m). The wind speed was from 0 to 0.2 m/s, the temperature was 18°C. The calorific value needed for this research was determined in previous study (Chupa & Adamenko, 2023). To assess the morphological composition of solid household waste, averaged data for 2020-2021, provided by the Municipal Enterprise "Polygon solid household waste", was used. These data were obtained in accordance with approved by Ministry of Housing and Communal Services methodological recommendations (Order of the Ministry of Housing and Communal Services of Ukraine No. 39, 2010).

Results

The main methods of disposal of solid household waste are the following. Burial is the easiest and cheapest method, but it has a number of negative consequences, such as soil, water and air pollution. Recycling is a process that allows to turn solid household waste into secondary raw materials that can be used for the production of new goods. Thermal processing is a process in which solid household waste is burned to obtain energy in the form of heat or electricity. Thermal processing of solid household waste has a number of advantages: it reduces the volume of solid household waste, which reduces the need for the construction of landfills, receives energy that can be used to provide heat and electricity; reduces greenhouse gas emissions as solid household waste is incinerated instead of landfilled. The increasing volume of waste and its environmental impact highlight the need for effective waste management practices. While thermal treatment offers a valuable means of waste volume reduction, concerns regarding pollutant emissions remain. Thermal treatment of MSW has some disadvantages: causes emissions of air pollutants such as nitrogen oxides, sulphur oxides, carbon dioxide, heavy metals and particulates; leaves behind waste such as ash, sludge, slag, boiler ash, effluent and emissions.

When planning the incineration of solid household waste, the following factors must be taken into account. Disposal technology: it can be incineration to obtain energy, incineration to obtain chemical products or landfill. Morphological composition: waste can consist of paper, plastic, metal, glass, organic substances, etc. Necessity of preliminary preparation of waste: waste may require grinding, sorting, separation of metal, etc. State of waste: waste can be dry, wet, contaminated, etc. Fractional composition: waste can be homogeneous or heterogeneous. Moisture: the moisture content of waste affects its energy value and composition of emissions. Slag and ash: slag and ash are formed during the burning process and require disposal. Emissions into the atmosphere during combustion are one of the most important indicators to consider, as they can have a negative impact on the environment.

According to data provided by the Municipal Enterprise "Polygon solid household waste" approximately 64-68% of solid household waste entering landfills is suitable for energy recovery. About 32% of solid household waste is not suitable for energy production, as it is non-combustible, includes glass and metal, as well as unsorted residue, which is not taken into account during laboratory studies and calculation of the energy potential of solid household waste. A study of the ash content of all types of fuel was conducted, namely 7 samples of solid household waste of different types, 7 samples of solid fuel pellets from different tree species and 2 samples of mixtures: a mixture that corresponds to the morphological composition of MSW landfill with Rybne village; an averaged mixture of wood pellets. 16 samples of 1,500 g were prepared according to the established component composition, which is given in the Table 1, another group of test samples was also prepared.

Table 1. Description of the investigated components of solid household waste and pellets in the samples

No.	Types of pellets	Components of solid household waste
1	Oak	Paper and cardboard
2	Pine 30%, beech 30%, oak 40%	Plastic
3	Pine 50%, beech 30%, oak 20%	Wood
4	Artichoke	Textile
5	Pine (1)	Rubber
6	Pine (2)	Bio-waste
7	Beech	Unsorted combustible residue

Source: made by the authors

Groups of samples of waste and solid fuel pellets were burned in a solid fuel NEUS boiler. After complete combustion of each of the test samples, the working part of the boiler was cleaned of ash and combustion products. A total of 16 fuel samples were prepared, of which 8 samples are solid household waste, and the other 8 samples are solid fuel pellets. All of this is presented in Figure 1.

a b c

Figure 1. Test samples and facility for burning them

Note: a – NEUS boiler; b – solid household waste; c – solid fuel pellets

Source: made by the authors

During the combustion process, a study of the emissions of harmful substances into the atmospheric air was carried out using the gas analyser OKSI 5M, as well as the air quality analyser CEM DT-9881, which measured solid particles. To obtain data on the levels of harmful substances, the technique of measuring pollutant emissions from stationary emission sources was used. Emission measurements were carried out directly in the chimney, in the centre of its diameter, at a distance of at least two diameters from the last bend. Measurements were carried out using a measuring probe (Fig. 2). Meteorological measurements were conducted at head height (2 meters).

Figure 2. Conducting research on atmospheric air pollution levels

Source: made by the authors

From previous studies by V. Chupa & Ya. Adamenko (2023) the calorific value was determined for each of the samples of solid fuel wood pellets and their averaged mixture, and different types of waste, as well as a mixture of solid household waste according to the morphological composition suitable for burning at the Rybne village landfill. In accordance with the standards for the maximum permissible emissions of pollutants from stationary sources, the values of the standards for the maximum permissible emissions of vaporous and gaseous inorganic compounds, as well as suspended solid particles of undifferentiated composition are given in Table 2 (Order of the Ministry of Environmental Protection of Ukraine No. 309, 2006).

Table 2. Norms of maximum permissible emissions of vaporous and gaseous inorganic compounds, as well as suspended solid particles undifferentiated by composition

The name of the substance	The amount of mass loss, g/h	Maximum permissible emissions, mg/m^3
Substances in the form of suspended solids particles undifferentiated in composition	500 <	50
Sulphur dioxide (dioxide and trioxide) in converted to sulphur dioxide	5,000 <	500
Nitrogen oxides (nitrogen oxide and dioxide) in terms of nitrogen dioxide	5,000 <	500
Carbon monoxide	5,000 <	250

Source: created by the authors

All the averaged results obtained during the study are shown in Table 3. The most important indicator from the point of view of the efficiency of obtaining thermal energy is the calorific value of the fuel, and from the point of view of the impact on the environment, it is the level of emissions of pollutants into the atmospheric air. Also, an integral part of this impact are solid volatile particles that negatively affect the human respiratory system.

Table 3. Calorific value and atmospheric emissions of the studied samples

Type of fuel	Calorie content, J/g	Dust 2.5	Dust 10	CO	NO	NO_x	NO_2	SO_x	SO_2	CO_2
Plastic	39,970.00	0.000968	0.277884	54	510	516	108	498	432	1.90%
Rubber	32,373.00	0.001275	0.324795	78	654	558	108	639	540	2.10%
A mixture of waste from the Rybne village landfill	18,487.9	0.000784	0.125671	37	258	282	144	256	72	1.50%
Pine 30%, beech 30%, oak 40%	18,399	0.000571	0.005463	21	24	6	36	24	27	0.10%
Oak	18,313	0.000461	0.003628	19	54	30	144	54	21	0.20%
Average pellet mixture	17,947.16	0.000510714	0.004117286	22	55	22	82	55	42	0.25%
Tree	17,947.00	0.000562	0.001287	34	342	432	72	339	108	0.60%
Pine 50%, beech 30%, oak 20%	17,882	0.000613	0.004273	24	42	17	108	42	10	0.30%
Artichoke	17,728	0.000487	0.003471	23	72	42	108	72	12	0.40%
Pine (2)	17,693	0.000581	0.003962	25	78	18	36	78	19	0.25%
Beech	17,668	0.000389	0.003285	17	54	30	72	54	17	0.15%
Pine needles (1)	17,643	0.000473	0.004739	24	60	24	72	60	42	0.35%
Textile	17,580.00	0.000751	0.124621	53	348	426	108	338	360	1.10%
Bio-waste	13,637	0.000543	0.001675	76	570	582	144	557	468	1.30%

Table 3. Continued

Type of fuel	Calorie content, J/g	Dust 2.5	Dust 10	CO	NO	NO_x	NO_2	SO_x	SO_2	CO_2
Paper, cardboard	13,457.00	0.000457	0.001354	43	426	492	108	418	288	1.50%
Unsorted combustible residue	9,622.00	0.000897	0.018467	45	426	492	72	409	612	1.70%

Source: created by the authors

According to the obtained data in the Table 3, a visualization of the obtained data using a summary graph is visible (Fig. 3). It can be noted that such types of solid household waste as plastic and rubber have a rather low level of moisture within the range of 3-5%, which accordingly has a positive effect on their combustible properties. All types of wood pellets are characterized by a low level of moisture and a sufficiently high level of calories, regardless of their origin (type of wood). Samples such as paper, textiles, wood waste, a mixture of solid household waste from the Rybne village landfill, unsorted combustible residue of solid household waste and bio-waste showed the worst indicators of the ratio of caloric content to moisture. The mass of bio-waste is the least suitable for obtaining thermal energy, without preliminary preparation, the moisture content can be significantly reduced with the help of preliminary drying, but this is an additional cost of thermal energy. For bio-waste, the best disposal solution remains composting.

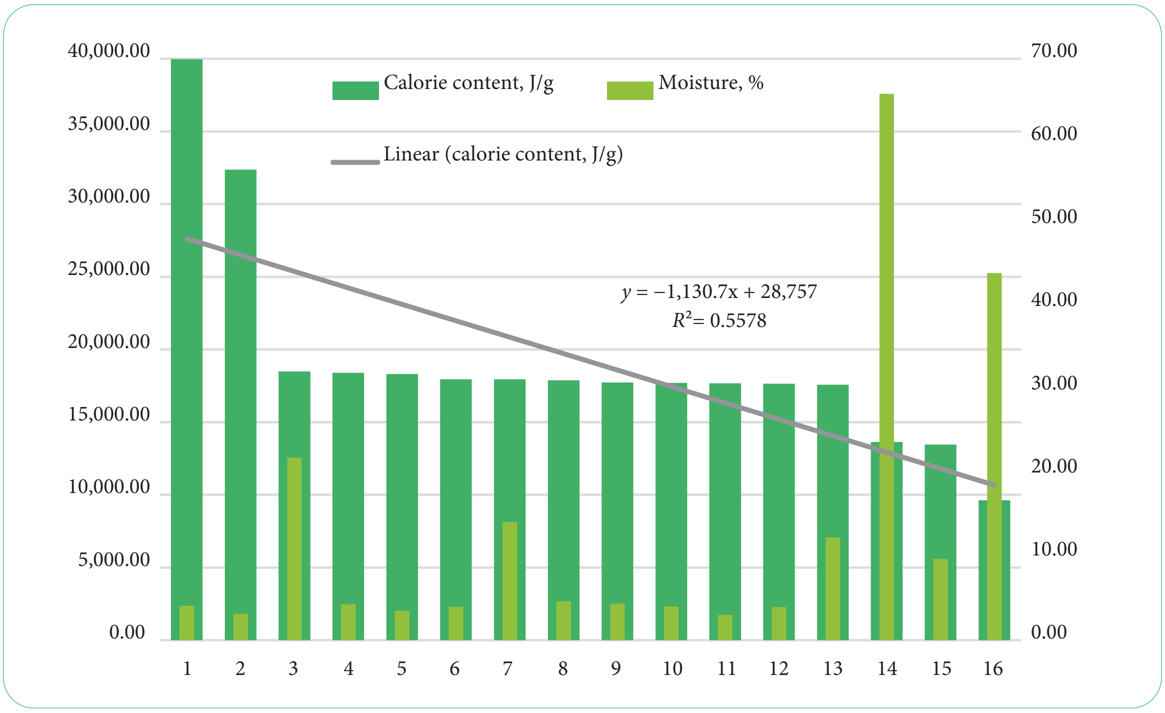

Figure 3. The ratio of caloric content and moisture level of experimental samples

Note: 1 – plastic; 2 – rubber; 3 – a mixture of waste from the Rybne village landfill; 4 – pine 30%, beech 30%, oak 40%; 5 – oak; 6 – average pellet mixture; 7 – tree; 8 – pine 50%, beech 30%, oak 20%; 9 – artichoke; 10 – pine (2); 11 – beech; 12 – pine needles (1); 13 – textile; 14 – bio-waste; 15 – paper, cardboard; 16 – unsorted combustible residue

Source: made by the authors

Figure 4 and Figure 5 illustrate the levels of emissions of harmful substances into the atmospheric air during the burning of solid household waste and solid fuel wood pellets, respectively. The blue line of the graphs indicates the level of thermal energy released during the burning of the test samples, the orange line indicates the norms of the maximum permissible output for such harmful substances as NO_x, SO_x and their derivatives NO, NO_2, SO_2, the grey line shows the normative level of the maximum permissible output CO carbon monoxide.

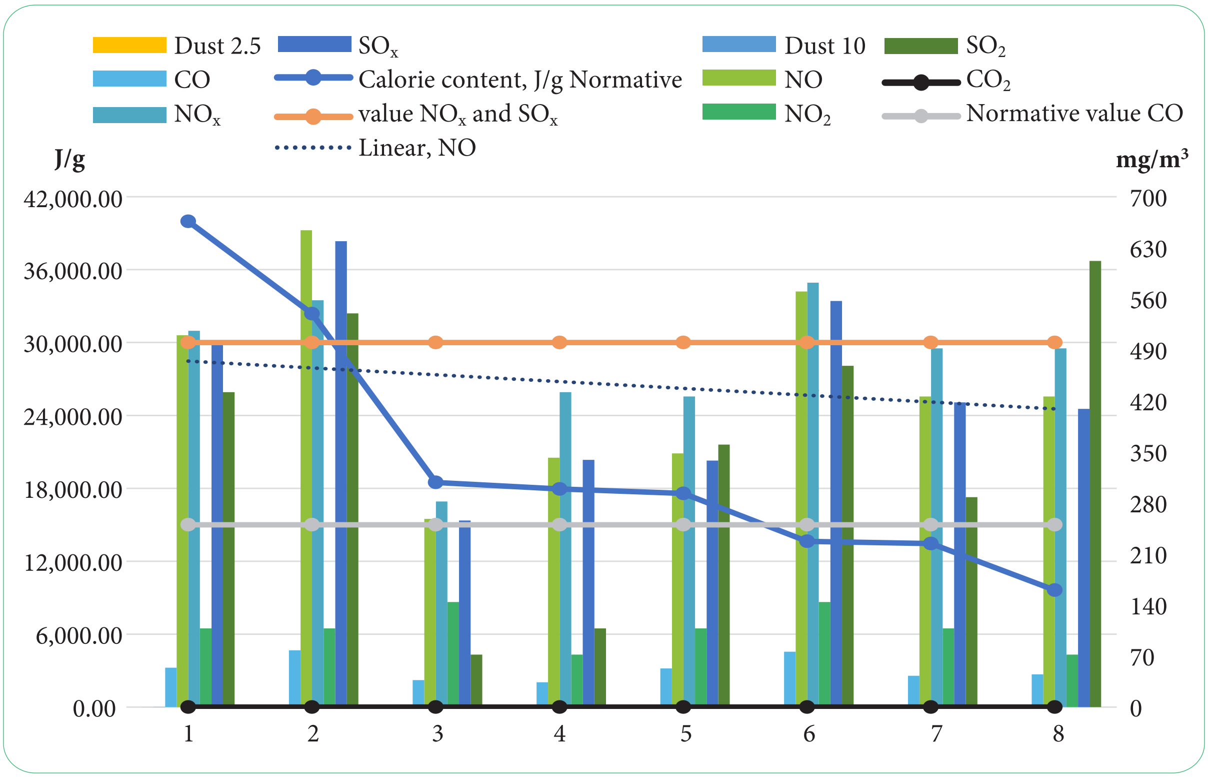

Figure 4. Graph comparing the level of caloric content and emissions into the atmosphere of solid household waste
Note: 1 – plastic; 2 – rubber; 3 – a mixture of waste from the Rybne village landfill; 4 – tree; 5 – textile; 6 – bio-waste; 7 – paper, cardboard; 8 – unsorted combustible residue
Source: made by the authors

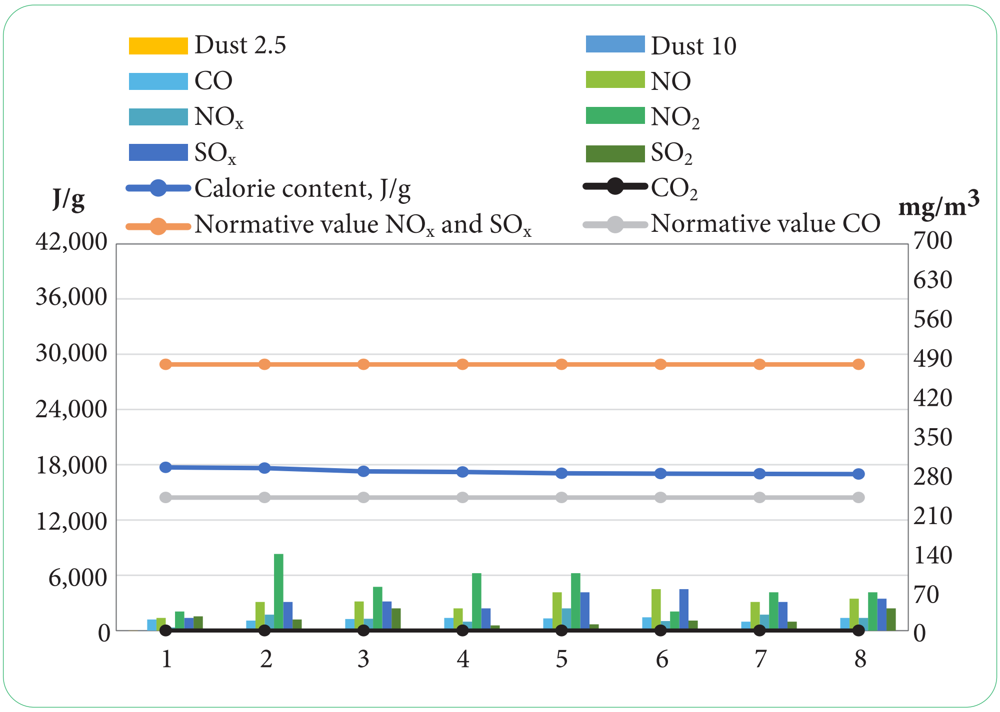

Figure 5. Graph comparing the level of caloric content and emissions into the atmosphere of solid fuel wood pellets
Note: 1 – pine 30%, beech 30%, oak 40%; 2 – oak; 3 – average pellet mixture; 4 – pine 50%, beech 30%, oak 20%; 5 – artichoke; 6 –pine (2); 7 – beech; 8 – pine needles (1)
Source: made by the authors

After analysing the graphs, it can be seen that the highest rate of emission of harmful substances into the atmospheric air is observed in samples of rubber, bio-waste and plastic. At the same time, the best ratio of caloric content (18,399 J/g) to atmospheric emissions is in the samples of the pellet mixture (Pine 30%, beech 30%, oak 40%). Also, the worst ratio of caloric content (9,622 J/g) to atmospheric emissions is observed in samples of unsorted combustible residue. Also, it can be noted that excess emission levels of pollutants such as NO_x and SO_x are observed in rubber, plastic and bio-waste, and excess CO emission levels are not observed, since the level of carbon monoxide characterizes the quality of the combustion process itself and its efficiency solid fuel installation.

Discussion

It's crucial to compare the calorific values of various waste types with studies conducted in different settings. A broader approach ensures comprehensive understanding and enables more accurate assessments of the energy potential inherent in various types of waste. Understanding the environmental impact of burning different waste types is crucial for making informed decisions about waste management practices.

The A.O. Popoola *et al.* (2023) research focuses on evaluating the calorific potential of MSW in Enugu, Nigeria, for electricity generation, providing comparisons across different landfill sites. This variation in waste composition and calorific values underlines the importance of regional studies in understanding waste-to-energy efficiency. Such comparisons validate the relevance of further research in this domain, including the investigation of emissions from waste combustion. Unlike the studies of the M.C. Unegg *et al.* (2023), who focused their research on the comparative analysis of CO_2 emissions with different types of waste management and J. Saleem *et al.* (2023), who considered only the same type of waste, such as plastic, authors of the presented research focused their attention on the study of toxic emissions from various types of waste. Several studies, like the one by M. Abis *et al.* (2020), analyse the state of MSW management in the EU, highlighting the importance of increasing recycling rates and optimizing ash recovery from incineration. This current research builds upon such efforts by investigating air pollutant emissions from various waste types during thermal treatment.

The study of thermal utilization of municipal waste and its impact on air emissions is a topical area. In the paper, the authors analyse pollutant emissions from the combustion of various types of waste and wood pellets. Their results confirm the dependence of emissions on the type of waste and combustion technology, with plastic, rubber, and bio-waste showing the highest levels of pollution. This study complements R. Nandhini *et al.* (2022) work by focusing on a specific waste composition at a landfill in Rybne, Ukraine. Burning technology is also important in thermal disposal of household waste. For example, the paper by C.I. Idumah (2022) examines the impact of different combustion technologies on pollutant emissions. This article complements existing research by studying the pollutant emissions of different types of waste and wood pellets made from different types of wood.

The work of A. Voronych *et al.* (2023) analysed the morphological composition of MSW. The approximate percentage of SW suitable for energy utilization from the total mass of SW entering landfills has been determined. The level of reduction in mass of MSW during incineration was determined. Some characteristic parameters of thermal treatment of SW by experimental method were determined. The location of this study coincides with this research, so the data obtained by the researchers formed the basis of this analysis and comparison of the obtained results. C. Yue *et al.* (2022) directed their research in a slightly different direction of analysis of the process of energy recovery from solid household waste, namely pyrolysis and the effect on this process of different proportions of gases in the reactor of the pyrolysis plant. This research on the contrary describes a less technically complex process of energy recovery from solid household waste, but the principles of using waste as a source of thermal energy are somewhat similar.

The authors of the study analysed the possibility of producing fuel pellets using bio-waste and its ash. The process of creating such fuel pellets is quite complicated, as the authors B.R. De Almeida Moreira *et al.* (2021) emphasize that this fuel is a possible substitute for coal. In authors research, the path of simpler processing of bio-waste than the production of coal from it was chosen. H. Tran *et al.* (2023) examine the emissions of pollutants into the atmosphere accompanying the production of fuel pellets from wood waste. The direction of such research is very interesting, since few people are engaged in researching the negative effects of the production process itself, in particular, this aspect is not taken into account in presented research, but in the following publications authors want to pay attention to it.

In their study, N. Bublienko *et al.* (2020) meticulously analysed emissions from the combustion of plant residues, which contrasts combustion of MSW and pellets in this study. Specifically, the authors considered emissions resulting from the combustion of fallen leaves and explored their cost-effective processing to produce a biostimulant. They investigated the environmental impact of these emissions, which can offer valuable insights into sustainable waste management practices. An interesting study is the work of Y. Zhang *et al.* (2022). The scientists analysed the emissions of pollutants into the atmosphere if co-combustion is carried out in different proportions of excavation waste with municipal waste. The authors concluded that such incineration with less than 40% of MSW mixed with excavation waste and a sufficiently low combustion temperature can not only improve the overall combustion of waste but also reduce emissions.

Pyrolysis technology allows to decompose solid household waste at a temperature of 500-900°C without access to oxygen. Gasification technology allows solid household waste to be decomposed at a temperature of 800-1000°C in the presence of oxygen. At the same time, combustible gases are formed, which can also be used for the production of electricity or heat. These technologies are promising for solving the problem of solid household waste, as they allow obtaining energy from solid household waste without negative impact on the environment (Pan *et al*., 2022; Lopushniak *et al*., 2023). In previous authors studies, the thermal potential of household waste was also analysed, and the possible calorific value of waste mixed with pellets made from wood and energy crops was calculated.

The study in question delved into the ecological efficiency of utilizing various types of solid fuel pellets and solid domestic waste as a substitute energy source. A critical factor considered was the balance between the fuel's calorific value, which signifies its energy potential, and the level of harmful substance emissions that impact the environment. Solid fuel pellets, specifically a blend of pine, beech, and oak in specific ratios, exhibited high efficiency.

Conclusions

High efficiency of solid fuel pellets conditioned primarily due to their combination of high calorific value and low emission levels, making them a favourable option for use in heat-generating systems that aim to minimize adverse effects on the atmosphere. On the contrary, unsorted combustible waste, which can also serve as fuel, presents a lower energy value and a higher level of harmful emissions. This makes it a less preferable choice from an environmental perspective, despite its potential for energy production. To effectively illustrate the findings of the study, a comparative graph was developed. This graph demonstrates the relationship between calorific value and emission levels for different fuel types. By plotting these variables against each other, the graph provides a clear visual representation of the trade-offs between energy potential and environmental impact. This graph can serve as a valuable tool for selecting the most efficient and eco-friendly fuel for specific needs. It allows users to consider their individual requirements for energy efficiency and environmental standards, thereby facilitating informed decisions about fuel choices.

The study underscores the importance of considering both energy efficiency and environmental impact when evaluating potential fuel sources. While some fuels may offer high energy output, their environmental costs may outweigh their benefits. Conversely, fuels with lower energy output but minimal environmental impact may prove to be more sustainable in the long run. In conclusion, the study provides a comprehensive analysis of the ecological efficiency of various fuels, offering valuable insights for those seeking to balance energy needs with environmental responsibility. The comparative graph developed from the study's findings serves as a practical tool for visualizing these trade-offs and making informed fuel choices. An additional direction of future research will be focused on the generalization and analysis of the obtained research results. Having combined the obtained results, it is planned to develop an automated calculation complex that will receive input data: calorific value, ash content and emissions into the atmospheric air during the burning of pellets and household expenses, and at the output will provide percentage values of fuel compositions according to the initial parameters needed.

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None.

Conflict of Interest

None.

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Дослідження викидів від спалювання пелет та твердих відходів в атмосферу

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Анотація. Проблема відходів стає все гострішою, оскільки кількість відходів і їх негативний вплив на довкілля зростає. Термічна обробка є одним із найефективніших методів зменшення об'єму відходів, але вона ж призводить до викидів забруднювачів в атмосферу. Тому вивчення викидів у повітря від спалювання різних типів відходів, а також пелет, виготовлених із різних типів деревини, було метою цього дослідження. Під час екскурсії на полігон твердих побутових відходів у с. Рибне були зібрані зразки відходів для подальших досліджень. Проведено порівняльний аналіз рівня викидів в атмосферне повітря суміші відходів, що відповідає морфологічному складу полігону твердих побутових відходів у с. Рибне. Також порівняльний аналіз проводився для рівня викидів в атмосферне повітря та калорійності кожного типу відходів, пелет та їхніх сумішей. Дослідження показало, що рівень викидів забруднювачів в атмосферне повітря залежить від типу відходів та технології їх спалювання. Найбільше викидів забруднювачів спостерігається під час спалювання пластику, гуми та біовідходів. Тверде паливо, таке як деревина, папір і текстиль, виділяє менше забруднювачів. Розроблено графік порівняння калорійності різних типів відходів та пелет із рівнями викидів в атмосферу. З графіка видно, що, як правило, чим вища калорійність палива, тим нижчі рівні викидів забруднювачів. Результати дослідження є цінними на практиці для покращення методів утилізації побутових відходів для виробництва теплової енергії, зокрема, для вибору паливних композицій, що мінімізують рівні досліджуваних забруднювачів у повітрі

Ключові слова: тверді побутові відходи; термічна утилізація; калорійність; викиди в повітря; тверді частинки