ЕКОЛОГІЧНІ ПРОБЛЕМИ В ЕНЕРГЕТИЦІ
ENVIRONMENTAL PROBLEMS IN ENERGY

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ANALYSIS OF USE OF TRAPA NATANS AS ALTERNATIVE FUEL FOR BOILER

The article considers the search for alternative fuel relevant for the present question. For example, the use of wood pellets or biomass. The use of biofuels can also put a stop to the biggest environmental problem - climate change on the planet. Biofuels have less effect on the greenhouse effect, because plants that then use as biofuels absorb carbon from the atmosphere and produce oxygen. The properties of Trapa natans spread and multiply rapidly, make it possible to consider it as an alternative fuel for boiler houses of the hot water supply system (HWS). Coal combustion is usually characterized by high combustion temperatures and contains more sulfur and nitrogen than wood and other biomass. This means that the burning of coal leads to the release of sulfur oxide and nitrogen oxides, as well as toxic pollutants that are bound by adsorption or absorption. Wood combustion smoke also contains gaseous air pollutants, which may have a number of adverse health effects. Among these gases are carbon monoxide, nitric oxide, acrolein, formaldehyde, benzene, and other organic compounds, including carboxylic acids, numerous saturated and unsaturated hydrocarbons, aromatic compounds, and oxygen organic compounds. Combustion of biomass, which, for example, as a result of salt water treatment or transport by sea, contains chlorine, can also lead to emissions of chloro-organic compounds. To establish a connection between the combustion heat and the calorific value of the substance, the equations of the chemical combustion reaction are analyzed. The calorific value of the fuel is calculated using the empirical formula proposed by D.I. Mendeleev. To do this, an analysis of the elementary composition of the fuel is performed, that is, the percentage of oxygen, hydrogen, carbon, sulfur, nitrogen, ash, water in it. The necessary amount of Trapa natans, firewood and coal required to heat 500 liters of water from 30 to 100 °C has been established. It has been proved that Trapa natans can be used as an alternative fuel for boiler systems of HWS for enterprises adjacent to reservoirs.

Keywords: *Trapa natans, water nut, alternative fuel, boiler houses, hot water supply systems, heat of combustion.*

Introduction

Every year, fossil fuel prices are rising, and their number is decreasing. Humanity has long been in search of alternative fuel. For example, the use of wood pellets or biomass. The use of biofuels can also put a stop to the biggest environmental problem - climate change on the planet. Biofuels have less effect on the greenhouse effect, because plants that then use as biofuels absorb carbon from the atmosphere and produce oxygen.

The properties of Trapa natans (Slingshot floating, teal, damn nut, water chestnut) spread and multiply rapidly, as well as its chemical composition, make it possible to consider it as an alternative fuel for boiler systems of hot water supply (HWS).

Goal and tasks

The purpose of the work is due to the need of mankind for alternative fuels, because the amount of natural fossil fuels is decreasing, and its use increases the amount of greenhouse gases, giving rise to the greatest environmental problem of the modern world.

Presentation of the main research material

The introduction of new renewable energy technologies and the search for alternative fuels is an effective way to overcome fuel and environmental problems.

The usefulness of fuels depends on many factors. Coal is usually characterized by high combustion temperatures and contains more sulfur and nitrogen than wood and other biomass. This means that combustion of coal leads to the release of SO_2 and nitrogen oxides (NO_x) (4% emissions SO_2 and 1% emissions NO_x worldwide) as well as toxic pollutants that bind to PM (suspended solids The situation is complicated by the fact that coal that is mined in certain geographical regions contains toxic elements such as fluorine, arsenic, selenium, mercury and lead. The combustion of such coal has been associated with poisoning with toxic compounds released by combustion [1].

$PM_{2,5}$ (suspended solid particles with aerodynamic diameter less than 2.5 μm) is one of the main air pollutants generated during combustion of solid fuels. Fine particles originating from wood burning are generally considered to be the best indicator of health effects; this pollutant is the most widely studied and the focus of most emission regulations.

Black carbon (BC) is one of the components of $PM_{2,5}$, which has a negative impact on health and is recognized as a short-lived pollutant that affects the climate [2]. As emissions from wood furnaces or devices for burning long wood floors cool or "aging," the BC adsorbs a number of gaseous hydrocarbons. When properly operated to optimize airflow, wood pellet furnaces emit much less BC and polycyclic aromatic hydrocarbons (PAH) than conventional wood furnaces [3].

Organic carbon (OC) is another component of *PM* that is directly emitted into the air when many solid fuels burn, and is also formed as a secondary pollutant. Organic and some inorganic emissions undergo rapid physicochemical transformation, followed by later reactions in the atmosphere [4]. The speed of many reactions depends on solar lighting (ultraviolet radiation), as well as on atmospheric temperature; this means that during the cold and dark periods of the heating season they flow much slower than in other, sunnier and warmer periods of the year. Unlike BC, aerosols containing OC tend to have a cooling effect on the climate. When small heaters are used, even an increase in combustion efficiency will practically not affect the level of BC emissions when burning a certain amount of fuel. However, more complete combustion will significantly reduce emissions of organic compounds and increase emissions of inorganic salts such as potassium and zinc sulphates, chlorides and carbonates, the composition of which depends on the type of biomass [5].

Smoke from wood (and other biomass) combustion also contains gaseous air pollutants, which may have a number of adverse health effects. Among these gases: CO, NO_x), cellular organic compounds (acrolein, formaldehyde, benzene), gaseous and suspended PAHs, as well as other organic compounds including carboxylic acids, numerous saturated and unsaturated hydrocarbons, aromatic compounds and oxygen organic compounds (aldehyde From biomass combustion, which, for example, as a result of salt water treatment or transport by sea, contains chlorine, can also lead to emissions of chloro-organic compounds. Combustion of coal is often accompanied by emission of SO_2 due to possible high sulphur content in this type of fuel [6].

Levoglucosan is a biomass combustion marker that is often used as an indicator to determine exposure to biomass-based fuel combustion products or to investigate source distribution. While the benefit of Levoglucosan as a marker of biomass combustion has already been proven, more research is needed to quantify the relationship between Levoglucosan levels and mass *PM* concentration in scenarios involving different types of wood and devices for its combustion [7].

When burning coal, elements and compounds that are particularly dangerous to human health can be released (fluorine, arsenic, selenium, mercury and lead); Household coal combustion can lead to the release of these pollutants into the indoor environment [6]. In a particularly difficult economic situation, people often resort to burning fragments of furniture, plastic and garbage. The combustion of these materials is accompanied by the release of highly harmful pollutants such as dioxins and lead.

The short-term effects of wood combustion particles and fossil fuel combustion particles are equally harmful to health. In animal experiments, 28 toxic contaminants, including 14 carcinogenic compounds and 4 cancer promoting agents, were proved to be present in the smoke from solid fuel combustion [8].

The association between increases in atmospheric daily concentrations of $PM_{2,5}$ and increases in mortality and hospitalization has been demonstrated in hundreds of epidemiological time series studies conducted in different climatic conditions and populations. Long-term exposure (years) to *PM* appears to have a greater impact on health than short-term (days), although it should be considered that there have been fewer studies of long-term exposure. The results of the studies suggest that the influence of *PM* not only causes acute manifestations of the disease, but can also accelerate the development of chronic diseases or even cause them [9]. In low-income countries, the long-term impact of high concentrations of pollutants in wood smoke was associated with lower respiratory tract infections (including pneumonia) in children, chronic obstructive pulmonary disease, decreased lung function and lung cancer in women, and stillborn and low birth weight [1].

For enterprises adjacent to the reservoirs, it is possible to consider Trapa natans as an alternative fuel for hot water boiler systems. Trapa natans is a one-year-old plant with a flexible stem 50-500 cm long, its floating leaves form a rosette with a diameter of up to 30 cm. The placement of rhombic leaf plates is mosaic. The flowers are single, surface, have four white petals. The upper fates of the calyx of the flower remain with the fruits, wooden and turn into spikes. The fruits are bone-shaped, have the appearance of four horns with a diameter of 2-5 cm [10]. The infancy root Trapa natans, unlike the root of all other plants, begins to grow not down, but up and only after the appearance of the stem bends with an arc and attaches to the soil. Trapa natans belongs to the group of hydrophytes rooted with leaves floating on water, which are characterized by a large amount of carbon and nitrogen and a low concentration of unstructured carbohydrates, mineral substances and organic acids [11].

When burning Trapa natans, carbon dioxide, nitrogen and ash are released, but in a smaller amount than when burning other fuels. Nitric oxide NO and nitrogen dioxide N_2O in the atmosphere are found together, so they are most often evaluated for their joint effect on the human body. Only near the emission source there is a high concentration of *NO*. During combustion of fuel in cars and thermal power plants, approximately 90% of nitrogen oxides are formed in the form of nitrogen monoxide. The remaining 10% is nitrogen dioxide. However, during chemical reactions, a significant part of NO is converted to N_2O, a much more dangerous compound. Nitrogen monoxide *NO* is a colorless gas. It does not irritate the airway, and therefore a person may not feel it. When inhaled, *NO*, like *CO*, binds to hemoglobin. At the same time, unstable nitrozo-connected is formed, which quickly goes into methemoglobin, while Fe^{2+} goes into Fe^{3+}. The Fe^{3+} ion cannot bind O_2 back and thus leaves the oxygen transfer process. The concentration of methemoglobin in the blood is 60-70 % considered lethal. But such a limit value can occur only in closed rooms, and in the open air it is impossible [12].

To calculate the amount of Trapa natans for heating water, the empirical formula of D.I. Mendeleev is considered.

Chemical reactions are accompanied by heat release or absorption, and the combustion reaction is always accompanied by heat release.

The combustion heat Q_g (J / mol) is the amount of heat generated by the complete combustion of one mole of matter and the conversion of the combustible matter into complete combustion products. In technical calculations, the calorific value of the fuel Q (J/kg or J/m^3) is more often used not the combustion heat Q_g.

Knowledge of the combustion heat and calorific value of the fuel is necessary to calculate the combustion or explosion temperature, explosion pressure, flame propagation rate and other characteristics. The calorific value of the fuel is determined either by experimental or calculated methods.

To establish a connection between the combustion heat and the calorific value of the substance, it is necessary to write down the equation of the chemical combustion reaction.

The product of complete carbon combustion is carbon dioxide:

$$C + O_2 \to CO_2$$

The product of complete hydrogen combustion is water:

$$2H_2 + O_2 \to 2H_2O_2$$

The product of complete sulfur combustion is sulfur dioxide:

$$S + O_2 \to SO_2$$

At the same time, nitrogen, halides and other incombustible elements are released in free form.

If the calorific value of the fuel is unknown, then it can be calculated using the empirical formula proposed by D. I. Mendeleev. To do this, you need to know the elementary composition of the fuel (equivalent fuel formula), that is, the percentage of the following elements in it:

- oxygen (O);
- hydrogen (H);
- carbon (C);
- sulfur (S);
- nitrogen (N);
- ash (A);
- water (W).

Fuel combustion products always contain water vapors, which are formed both due to the presence of moisture in the fuel and during hydrogen combustion. Spent combustion products leave industrial plant at temperature higher than dew point temperature. Therefore, the heat generated by condensation of water vapor cannot be usefully used and should not be taken into account in thermal calculations.

For calculation, a lower calorific value Q_n of the fuel is usually used, which takes into account heat losses with water vapors. For solid and liquid fuels, the value of Q_n (MJ/kg) is approximately determined by the Mendeleev formula:

$$Q_n = 0{,}339[C] + 1{,}025[H] + 0{,}1085[S] - 0{,}1085[O] - 0{,}025[W], \quad (1)$$

where the percentage (%) of the corresponding elements in the fuel composition is indicated in parentheses.

This formula takes into account the heat of exothermic reactions of carbon, hydrogen and sulfur combustion (with a plus sign). Oxygen included in the fuel partially replaces air oxygen, so the corresponding term in formula (1) is taken with the sign "minus." When moisture evaporates, heat is consumed, so the corresponding term containing W is also taken with the sign "minus" [13].

The solution is to provide alternative fuel to enterprises located near reservoirs.

To do this, it is necessary to determine the amount of Trapa natans needed to heat 500 liters of water from 30 to 100 °C, if 5% of the heat generated during combustion is consumed for heating, and the heat capacity of water *c* = 1 kcal (kg · deg) or 4.1868 kJ (kg · deg). The composition of Trapa natans is examined according to the above elements, as shown in Fig. 1 [14].

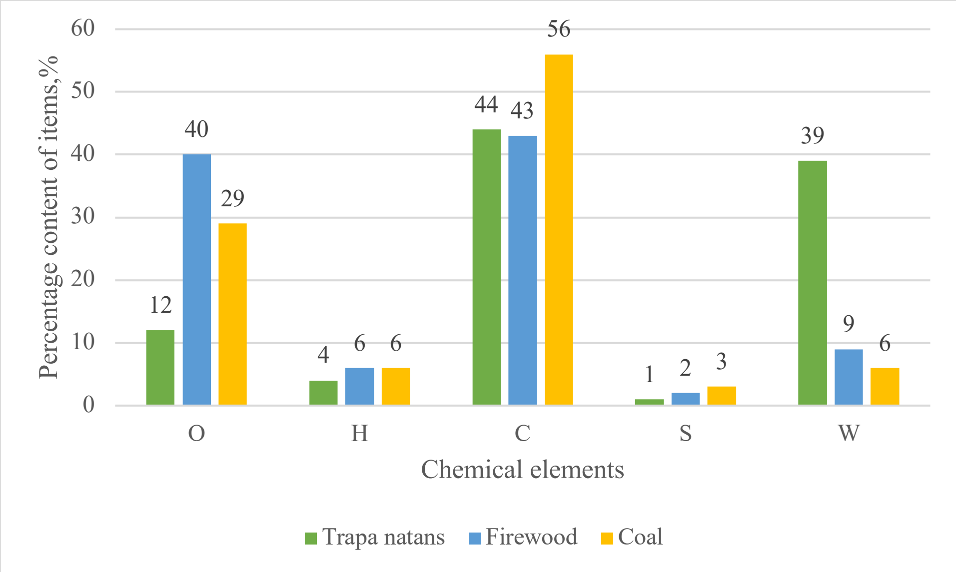

Figure 1 – Elemental composition of Trapa natans, firewood and coal

Determine the amount of heat required to heat *m* = 500 kg of water:

$$Q_1 = c \cdot m \cdot \Delta T = 4{,}1868 \cdot 500 \cdot (100 - 30) = 146{,}538\ MJ. \quad (2)$$

We will find the calorific value of Trapa natans according to the Mendeleev formula (1):

$$Q_n = 0{,}339 \cdot 44 + 1{,}025 \cdot 4 + 0{,}1085 \cdot 1 - 0{,}1085 \cdot 12 - 0{,}025 \cdot 39 = 16{,}847\ MJ/kg. \quad (3)$$

So, the amount of heat spent on heating water during combustion of 1 kg of Trapa natans (taking into account that 5% of the heat ($a = 0{,}05$) released during combustion is used for its heating):

$$Q_2 = a \cdot Q_n = 0{,}05 \cdot 16{,}847 = 0{,}842\ MJ/kg. \quad (4)$$

At the same time, the amount of Trapa natans required to heat 500 liters of water from 30 to 100 °C:

$$M = \frac{Q_1}{Q_2} = \frac{146{,}538}{0{,}842} = 174{,}04\ kg. \quad (5)$$

Thus, 174 kg of Trapa natans is required to heat water in the boiler HWS.

To draw the necessary conclusions, we compare fuels such as water nut, firewood and coal. To do this, the necessary calculations were made for the same conditions, only for other fuels.

The mean values of firewood composition were studied and presented in Fig. 1 [15]. Using these values, we will find the calorific value of firewood according to the Mendeleev formula (1):

$$Q_n = 0{,}339 \cdot 43 + 1{,}025 \cdot 6 + 0{,}1085 \cdot 2 - 0{,}1085 \cdot 40 - 0{,}025 \cdot 9 = 16{,}379\ MJ/kg. \quad (6)$$

At the same time, the amount of heat spent on heating water during combustion of 1 kg of firewood (taking into account that 5% of heat ($a = 0{,}05$) released during combustion is used for its heating):

$$Q_2 = a \cdot Q_n = 0{,}05 \cdot 16{,}379 = 0{,}818\ MJ/kg. \quad (7)$$

We determine the required amount of firewood required for heating 500 liters of water from 30 to 100 °C:

$$M = \frac{Q_1}{Q_2} = \frac{146{,}538}{0{,}818} = 179{,}14\ kg. \quad (8)$$

179.14 kg of firewood is required to heat water in HWS.

Coal composition is investigated and is presented in Fig. 1 [15]. We use these values to find the calorific value of coal according to the Mendeleev formula (1):

$$Q_n = 0{,}339 \cdot 56 + 1{,}025 \cdot 6 + 0{,}1085 \cdot 3 - 0{,}1085 \cdot 29 - 0{,}025 \cdot 6 = 22{,}163\ MJ/kg. \quad (9)$$

Under these conditions, the amount of heat spent on heating water during combustion of 1 kg of coal (taking into account the fact that 5% of the heat ($a = 0{,}05$) released during combustion is used for its heating):

$$Q_2 = a \cdot Q_n = 0{,}05 \cdot 22{,}163 = 1{,}108\ MJ/kg. \quad (10)$$

So we find the required amount of coal needed to heat 500 liters of water from 30 to 100 °C:

$$M = \frac{Q_1}{Q_2} = \frac{146{,}538}{1{,}108} = 132{,}25\ kg. \quad (11)$$

To heat water in the boiler HWS, 132.25 kg of coal is needed.

The technology of underground coal mining in Ukraine is inherently quite costly. The problem of high cost and poor quality of domestic coal negatively affects the economic and environmental performance of enterprises. It is clear that plant biomass cannot compete with traditional hydrocarbon fuels in terms of energy efficiency, but even their partial substitution allows improving the economic and environmental situation in the country. However, a number of factors hinder the widespread introduction of plant biomass into thermal energy. Consequently, there is a need to reduce the costs of traditional fossil fuels and to reduce harmful emissions to the environment through the use of plant biomass as a renewable energy source. And first of all, enterprises that are adjacent to reservoirs with an active growth of water nut.

Conclusions

The article investigated that the slingshot can be used as fuel for boiler systems of the HWS. Chemical combustion equations were analyzed to establish a connection between the combustion heat and the calorific value of the substance. We determine the required amount of Trapa natans required to heat 500 liters of water from 30 to 100 ° C, which turned out to be less than the amount of firewood by 5.1 kg.

Using empirical dependence, the calorific value of Trapa natans was established. It has been proven that this plant can be used as an alternative fuel for boiler houses of the HWS for enterprises adjacent to reservoirs.

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АНАЛІЗ МОЖЛИВОСТІ ЗАСТОСУВАННЯ TRAPA NATANS ЯК АЛЬТЕРНАТИВНОГО ПАЛИВА ДЛЯ КОТЕЛЕНЬ

В статті розглянуто актуальне для сьогодення питання пошук альтернативного палива. Як приклад, використання деревних пелет або біомаси. Використання біопалива також може призупинити найбільшу екологічну проблему – зміну клімату планети. Біопаливо має менший вплив на парниковий ефект, адже рослини, які потім використовують, як біопаливо, поглинають вуглець з атмосфери та виробляють кисень. Властивості Trapa natans швидко розповсюджуватися та розмножуватися, дають можливість розглядати його як альтернативне паливо для котельнь системи гарячого водопостачання (ГВП). Спалювання вугілля зазвичай характеризується високими температурами горіння і містить більше сірки та азоту, ніж деревина та інші види біомаси. Це означає, що спалювання вугілля призводить до виділення оксиду сірки і оксидів азоту, а також токсичних забруднювачів, які зв'язуються шляхом адсорбції або поглинання. Дим при спалюванні деревини містить також газоподібні забруднювачі повітря, з якими може бути пов'язаний ряд несприятливих наслідків для здоров'я. Серед цих газів: оксид вуглецю, оксид азота, акролеїн, формальдегід, бензол, та інші органічні сполуки, включаючи карбонові кислоти, численні насичені і ненасичені вуглеводні, ароматичні з'єднання і кисень органічні сполуки. Від згоряння біомаси, яка, наприклад, в результаті обробки солоною водою або транспортування по морю містить хлор, може призводити також до викидів хлорвмісних органічних сполук. Для встановлення зв'язку між теплотою згорання і теплотворною здатністю речовини проаналізовані рівняння хімічної реакції горіння. Розрахована теплотворна здатність палива за допомогою емпіричної формули, запропонованої Д.І. Менделєєвим. Для цього виконано аналіз елементарного складу палива, тобто процентний вміст в ньому кисню, водню, вуглецю, сірки, азоту, золи, води. Встановлена необхідна кількість Trapa natans, дров та вугілля, необхідних для нагрівання 500 літрів води від 30 до 100 °С. Доведено, що Trapa natans можна використовувати як альтернативне паливо для котельнь системи ГВП для підприємств прилеглих до водосховищ.

Ключові слова: *Trapa natans, водяний горіх, альтернативне паливо, котельні, системи гарячого водопостачання, теплота згоряння.*

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