Thermal utilization of spent sorptive material from phythogenic waste

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Abstract. The thermal utilization of spent sorptive materials based on phythogenic waste in a pulsating combustion unit is proposed. The combustion temperature was determined based on the method of differential scanning calorimetry and derivatography. The hazard class of the produced ash is calculated on the basis of elemental analysis.

Recently, the material needs of the population are growing and, as a result, the problems of environmental pollution are still present. Over the years, many methods have been developed for the purification of water bodies from organic and inorganic pollutants, but along with this, as a secondary environmental problem, there is the problem of recycling the waste sorptive materials (SM) formed by metal ions and oil.

There are various methods of recovering polluted substances in the process of water purification:

1. Chemical recovery. This method is performed using liquid or gaseous reagents at a temperature of up to 100 °C and causes desorption or sorbate destruction. Solutions of salts, acids, alkalis, and some organic solvents (carbon tetrachloride) are most commonly used [1].

2. Thermal regeneration. The technology is carried out by heating the SM with steam or inert gas. For example, desorption of caprolactam (300-340 °C), desorption of xylene (260-280 °C). Desorption products are disposed of after condensation [1].

3. Thermal and electrothermal regeneration. These methods are based on the sequential thermal degradation of the sorbate to volatile products and condensing intermediates, followed by reactivation and afterburning of all volatile products [1].

The choice of the regeneration method is decided in each specific case, taking into account the properties of the sorbent and the sorbent substance, the depth of purification and technical and economic indicators [2, 3].

To date, there are various methods of disposal of spent fuel, the main of which are:

1) creation of fuel briquettes based on the used SM;
2) disposal of sorbents in the soil;
3) use as a filler in the manufacture of laminated building materials;
4) use of Portland cement binding during hydration control in the composition;
5) incineration in pulsing combustion units.
The use of the first two proposed technologies is unacceptable from environmental point of view, since they lead to secondary pollution of the biosphere by chemical degradation products.

The most popular and widespread methods of disposal of spent sorbents are thermal methods, in particular, combustion in pulsing combustion units. During flame treatment, there is a complete oxidation of combustible compounds and decomposition of harmful components.

The use of pulsing combustion units allows you to obtain energy by burning waste, and also neutralizes waste by completely destroying it. The temperature in the combustion chamber of the plant is more than 1100 °C, which contributes to the complete burning out of the organic component of the sorbents.

Pulsing combustion units have a number of advantages:
- simple hardware design, small installation dimensions;
- efficient use of energy resources;
- intensive convective heat transfer;
- the concentration of toxic substances in the gas combustion products is below the maximum permissible concentration.

As samples for waste disposal by incineration, we studied spent sorptive materials (SM) based on phythogenic waste: bran coats of wheat grains (BCWG), barley (BCBG), oats (BCOG) and autumn leaf litter (ALL), formed as a result of the elimination of emergency oil spills on the surface of water bodies [4] and the adsorption treatment of water from dissolved oil and metal ions [5].

At the first stage, to determine the minimum temperature at which the spent SM should be burned, the decomposition characteristics of BCGV were determined using the method of differential scanning calorimetry and derivatography (Figure 1).

![Figure 1. Curves of thermogravimetry and differential scanning calorimetry of the BCBG.](image)

The temperature dependences of the decomposition of BCGV have 5 stages with maxima at 93 °C, 350 °C, and 476 °C, corresponding to endochemical effects. The curves of the sample mass loss show that the decomposition of BCGV begins at a temperature of 200 °C and ends at a temperature above 500 °C. Thus, it was determined that the temperature above 470 °C is necessary for the combustion of the organic component of the BCGV, while the loss of the sample mass was 98.77 %. It is known that the temperature in the combustion chamber of the plant was more than 1100 °C, which guarantees complete burnout of the organic component of the BCGV.

The spent fuel was burned in a pulsing combustion unit. The installation diagram is shown in Figure 2 [6].
The spent SM in the sack tare was placed in the loading unit 3. After packing the shaft, the burner unit was started. From highly heated gases, the waste flamed out. The gas stream began to rotate intensively around the waste when the fan unit 6 was turned on, exposing them to temperature and mechanical control. The burner unit 8 functioned as an igniter and a pulsation generator. As a result, heat and mass exchanging processes are reliably activated in the combustion chamber. The burner unit operates in acceleration modes and forms a pulsating high-temperature gas jet and runs on low-grade liquid fuel. The pulse jet performs a number of functions:

a) mixing of the combustible steam-and-gas mixture;
b) waste ignition;
c) intensification of heat and mass exchange between the gas and solid phases.

The ash (mineral content) that has gone into the dump must be disposed of or considered for use as a secondary material resource. To do this, it is necessary to determine the volume and hazard class of the produced waste. Since sorptive elements can be manufactured in various designs and sizes, the ash volume was calculated per 1 kilogram of spent sorptive material, the percentage of oil, water, and sample, in which 55, 25, and 20 %, respectively. Thus, during the thermal utilization of 1 kg of spent SM, 95 g of ash is produced. In order to determine its hazard class, its elemental analysis was carried out, the results of which are in Table 1.

**Table 1.** Calculation of the hazard class of ash formed after thermal processing of spent SM, based on the composition.

| Sample            | Zn  | Cu  | Fe  | Mn  | Ni  | Cr  | Ti  | V   | Ca  | K   | Cl  | S   | C_{les} |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|
| 1                 | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 18     |
| ALL+ Fe(II)       | 0.6 | 0.007 | 1.4 | 0.007 | 0 | 0.07 | 0 | 76 | 8.2 | 0 | 0.6 | 4 |        |
| ALL+ oil          | 0.2 | 0.2 | 4.5 | 1.6 | 0.1 | 0 | 0.2 | 0.5 | 51 | 12 | 3.7 | 23 | 4      |
| BCOG+oil          | 1.2 | 1.9 | 3.1 | 0.81 | 2.1 | 5.4 | 0.3 | 0.04 | 2 | 0.1 | 6 | 6.4 | 3     |
| BCOG+Zn(II)       | 0.7 | 0.4 | 16.7 | 0.1 | 0 | 0.1 | 0 | 6 | 16 | 7.1 | 2.4 | 4     |
| BCWG+ oil         | 0.04 | 0.05 | 1.3 | 0.03 | 0.06 | 0.06 | 0 | 0.15 | 1.1 | 7.4 | 0 | 4.6 | 3     |
| BCWG+Cu(II)       | 0 | 5.1 | 14.7 | 0.2 | 0.01 | 0.1 | 0.3 | 0 | 20 | 13 | 2.8 | 4.2 | 4     |
| BCWG+Zn(II)       | 0.3 | 0.3 | 5.9 | 0.1 | 0.08 | 0 | 0.2 | 0 | 11 | 17 | 8.2 | 3.1 | 5     |
| BCBG+ oil         | 0.4 | 0.1 | 5.3 | 0.05 | 0.09 | 0.16 | 0.08 | 0.14 | 2.5 | 1.8 | 0 | 5.9 | 3     |
| BCBG+Fe(II)       | 0.9 | 0.3 | 37.8 | 0 | 0.1 | 0.1 | 0.3 | 0 | 6 | 16 | 8.3 | 2.3 | 4     |
| BCBG+Ni(II)       | 0 | 0 | 28.1 | 0 | 8.1 | 0 | 0.1 | 0 | 5 | 16 | 3.3 | 3.1 | 4     |
Thus, a thermal method for the disposal of spent sorptive material based on lignocellulosic-based materials in a pulsating combustion unit at a temperature of 1100 °C is proposed; the composition and hazard class ($C_{\text{Hax}}$) of ash produced as a result of burning spent bran shells of cereals and leaf litter with sorbed metal ions (hazard class 4), oil (hazard class 3) is determined and calculated.

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