Design of a laboratory installation for studying the effects of ultraviolet radiation and ozonation on organic compositions, unsorted municipal and medical waste

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Abstract. The article presents the design process of a laboratory setup for studying the ultraviolet effect and ozonation on multifractional unsorted production and consumption wastes, including medical ones. The tasks, structural and functional diagram of the installation are formulated. The requirements for the constituent elements are defined. The process of designing and selecting components is described.

The existing system of solid municipal waste management in the Russian Federation is not capable of providing access to a model with conditionally zero burial by 2025. However, it is necessary to note a significantly increased attention from the federal and regional authorities to this problem and systemic positive changes. At the same time, as of today, the collection and disposal of MSW without separation still accounts for about 80% and leads to the withdrawal of land from sustainable circulation (over 50 thousand hectares are occupied by landfills).

The key guidelines for sustainable development of the waste management industry should be identified:
• bringing the total share of recycled and purposefully processed waste to 100%;
• elimination of the negative impact of waste and its products on the ecosystem through 100% replacement of technologies and materials that do not support natural circulation and biodegradation.

The current state of the problem clearly contrasts with the proposed guidelines for the sustainable development of the industry, which determines the relevance of the technologies for thermal destruction (burning) of unsorted fractions of municipal waste, as technologies for the transition process. This approach allows reducing the volume of waste disposal by an order of magnitude and eliminates the possibility of biological pollution of ecosystems. At the same time, protection of the atmosphere from pollution by waste products requires increased attention. The modern morphology of wastes and the imperfection of the widespread technological solutions of thermal degradation predetermine the need for research aimed at solving the following problems:
• search for solutions to improve energy efficiency and environmental safety of technological solutions for thermal destruction of waste;
• development of technologies for non-thermal methods of intensifying the destruction of composite materials and polymers;
• Search for effective solutions for the decontamination and reduction of the hazard class of transported waste (especially medical waste).

To increase the efficiency of the process, reduce the mass of unsorted waste and the cost of disposal, it is proposed to introduce the stage of preliminary processing and preparation for subsequent disposal by thermal methods. The integration of the pre-treatment stage makes it possible to reduce waste volumes, reduce the hazard class and increase the energy efficiency of subsequent thermal waste destruction.

During the analysis of literary sources, a choice was made in favor of ultraviolet radiation and ozonation technologies as the most promising in solving the tasks.

Ultraviolet exposure to the far spectrum penetrates the cell walls and destroys the nucleic acids of DNA and RNA. Ultraviolet disinfection consists in the absorption of radiation by nucleic acids, as a result of which cells lose their ability to divide. As a result, the selected wavelength spectrum of ultraviolet radiation in the range of 160 - 260 nm.

The ozonation process is triggered by far UV radiation in the selected range due to the use of UV lamps with quartz glass. Ozonation contributes to the destruction of hazardous chemicals, tobacco smoke, organic substances, detergents and cleaning products, products of combustion and mold, fungi and bacteria. All chemicals that are in the air, reacting with ozone, decompose into harmless compounds: carbon dioxide, water, oxygen and saturated oxides.

The technology itself plays a key role in the environmentally friendly and safe disposal of waste. In order to make it possible to study the mechanism of the effect of ultraviolet radiation and ozonation on unsorted waste fractions, we formulated the basic requirements for the designed laboratory installation:

1. Sealed enclosure with a volume of 14 liters.
2. An interned pair of UV sources of different spectra.
3. Monitoring ozone concentration in the chamber.
4. Inlet and outlet gas channel with emergency pressure relief system.
5. Temperature monitoring in the range of 25-55 °C.
6. Automation of supervisory control of process parameters in the chamber.

In accordance with the specified requirements, a structural-functional scheme has been developed:
In the study of the interaction of ultraviolet radiation and ozone with waste, it is necessary to ensure the maximum interaction area, which is impossible with the samples stationary. Thus, the installation functionality should be supplemented by the possibility of mixing samples. The solution to this problem is provided by the following technical solution: automated reversible drive, forced waste mixing system.

The efficiency of the mixer is determined by the geometric characteristics of the fractional composition of the waste. Based on an analysis of the experience of the Dresden Technical University of Germany in terms of studying the physicochemical properties of waste, we proposed a fraction dimension of 10 mm.

Preliminary study of the installation model was carried out in the Autodesk AutoCAD software environment, which allowed us to optimize a number of design decisions at the design stage and accelerate the creation of an experimental sample.
The danger of hard ultraviolet radiation to humans, along with the aggressiveness and toxicity of ozone, have determined high demands on the materials of the installation casing. During the analysis of the properties of structural materials, we selected as the main ones: stainless steel and fluoroplastic.

To achieve the tightness of the structure, fluoroplastic gaskets are used, since fluoroplast has unique technical characteristics:

- Resistance to chemical attack.
- Low coefficient of friction.
- Resistance to adhesion to other surfaces.
- Heat resistance - the flexibility and elasticity of the material are maintained at temperatures in the range from -70 ° to +270 ° C.
- Minimum surface tension.
- Floroplast perfectly lends itself to mechanical processing (drilling, grinding, milling).

Stainless steel is inert to these substances and does not corrode upon contact with acetone, toluene, alcohols, ammonia, flammable solvents, nitrocellulose varnishes, perchlorethylene, trichlorethylene, potassium and sodium alkali, phosphoric acid, sulfuric acid, etc.

For uniform ultraviolet irradiation, the housing makes a cyclic rotational movement around the longitudinal axis with an amplitude of 120 degrees by means of an electric drive paired with a reduction gear. The drive is controlled using standard Arduino solutions. Power supply is organized through a standard 5A driver. The intensification of the ozonation process is provided by a flag type initiator freely suspended in the chamber.

The tightness of the housing is ensured by fluoroplastic gaskets. Tubular type UV lamps are fixed with stainless steel clamps.

The installation is mounted on a welded steel frame 250 × 850 × 370 mm from a rectangular profile 1 mm thick.
Fig. 2. Installation sketch
The developed and designed installation will allow obtaining experimental data on the morphological and elemental composition of the exhaust gases, optimal from the point of view of the development of auto-destruction, the morphological and elemental composition of the samples of unsorted waste, as well as the change in the mass of the samples after processing.

The next step is to conduct experiments to study the effects of ultraviolet and ozone on unsorted waste:

- The amount of harmful chemicals in the exhaust gas after the primary treatment of waste
- The amount of harmful chemicals in the mass of samples before - after the primary treatment of waste
- Change in sample weight before - after in primary waste treatment
- Changes in the elemental composition of the exhaust gas after the addition of various fractions after the primary treatment of waste.

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