Commissioning of a laboratory setup for studying the effects of ultraviolet and ozone on multifractional, unsorted production and consumption wastes

T M Abdullin¹, I R Gilmanshin¹,²

¹Kazan Federal University, Kazan, Russia, 420008
²Kazan National Research Technical University named after A N Tupolev, Kazan, Russia

is-er@yandex.ru

Abstract. The article describes the process of commissioning carried out during the testing of the designed and manufactured laboratory installation for studying the effects of ultraviolet radiation and ozone on unsorted fractions of production and consumption waste, including medical waste. A detailed description of the installation is made, the characteristics of the elements of a power electric drive, metrological strapping and automation are given.

The study in the field of increasing the efficiency of thermal methods for the destruction of production and consumption wastes became especially relevant due to the sharp increase in the volume of municipal solid waste in large cities and megacities. The fractional composition of waste in the Russian Federation is shifting in favor of polymers and composites based on them. The recently actively developing sector of the separate collection of secondary use is still not able to provide 100% recycling. The main prerequisites are organic inclusions and low profitability of processing contaminated and composite fractions.

Installation developed by the joint scientific team of the Engineering Institute and the Chemical Institute. A.M. Butlerov Kazan University will allow to conduct targeted research on the interaction of ultraviolet radiation and ozone with model compositions of municipal and medical waste.

The key elements of the setup are a pair of ultraviolet lamps with differentiated emission peaks: a UV lamp with a peak wavelength of 185 nm and a UV lamp with a peak wavelength of 254 nm.

The choice of ranges was due to the need to provide a combined effect on the organic and polymer fractions of ozone wastes and the bactericidal effects of ultraviolet radiation. [15, 16]

Sources of ultraviolet radiation are traditionally used for the disinfection of various environments and the generation of ozone. The highest, 35-45%, efficiency of converting electric energy to ultraviolet radiation has low-pressure mercury lamps. The specific power of ultraviolet radiation ranges from 0.2 W / cm for mercury to 4 W / cm for amalgam lamps.

The radiation spectrum of a low-pressure mercury discharge is characterized by two resonant UV lines: 254 and 185 nm. Radiation with a wavelength of 254 nm has a pronounced bactericidal effect, while radiation with a wavelength of 185 nm serves as an active initiator of the formation of ozone. Radiation with a wavelength of 185 nm is actively absorbed by molecular oxygen and water vapor, followed by the generation of ozone and radicals (OH⁻).
In practice, a combination of 2 sources of ultraviolet radiation with wavelengths of 254 and 185 nm is used for the photochemical purification of various media from harmful substances and odors due to the generation of radicals and photochemical decomposition reactions. The paired effect is enhanced by the absorption of radiation at 254 nm by ozone with the formation of a highly active oxygen radical.

Figure 1 shows installation sketches with detailing of structural elements.

Fig. 1 of a laboratory setup for studying the effects of ultraviolet and ozone on multifractional, unsorted production and consumption waste.

1. Stainless steel working chamber, 2. Inlet and outlet gas valve, 3. Sources - UV radiation, 4. Flanged activator valves, 5. Flanges, 6. Fluoroplastic gaskets, 7. End caps, 8. Hardware, 9. Bearing nodes, 10. Drive shaft, 11. Protective coupling, 12. Lowering gear, 13. Power electric drive, 14. Installation bed.

In the process of experimental work, the initiation of ozone formation is provided by UV - Lama 1 (with a peak wavelength of 185 nm), UV - lamp 2 (with a peak wavelength of 254 nm) provides decontamination and reduction of the hazard class of the loaded volume of waste. Uniform irradiation and intensification of the chemical interaction provides a cyclic movement of the housing around its axis with an amplitude of 120° and a flag activator on a pendulum suspension.

Metrological piping of the installation provides monitoring of ozone concentration, temperature and humidity in the chamber.

Monitoring of ozone concentration is carried out by a pair of sensors of the MQ131 series (low concentration and high concentration) Fig. 2. The MQ131 is a semiconductor gas sensor consisting of
a heater circuit and a sensor circuit. The MQ131 sensor requires a minimum preheat time of 48 hours before yielding consistent results (also called “burnout” times). At the same time, there is a calibration, it regulates the value of the base resistance and the time required to heat the sensor and obtain consistent readings (reading time). It is controlled by Arduino: heater, calibration, environmental control (temperature and humidity) to obtain more accurate data. Conclusion of values in ppm, ppb, mg / m$^3$, μg / m$^3$.

Humidity and temperature are monitored using HTU21D sensors. The calculations are made by the programmable controller Arduino Uno R3.

During commissioning, the operability and safety of all components of the structure were monitored, the operation of automatic control of the power electric drive and the operator's automated workplace was evaluated.

During the experiment, the operability of the developed design of the laboratory setup was confirmed. The performance of the metrological harness of the installation of an automatic power drive automatic control system was confirmed.

A low concentration sensor (connected to the workstation for centralized monitoring and process control) monitors the safety of structures during the experiment (tightness control of welded and detachable joints is carried out).

A high concentration sensor (connected to the automated workstation for centralized monitoring and process control) monitors the concentration of ozone in the working chamber of the installation during the experiment (values are displayed in ppm, ppb, mg / m$^3$, μg / m$^3$, depending on the settings of the calculator).

A combined temperature and humidity sensor (connected to the workstation for centralized monitoring and process control) monitors the state of the gas environment in the installation chamber.

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

- The quantitative and qualitative composition of the exhaust gases after the primary waste treatment (by means of gas mass spectrometry);
- Change in sample weight before and after in primary waste treatment;
- Dependence of the elemental composition of the outgoing gas on the fractional and elemental composition of the waste.

References

[1] Shashkov I.V. Utilization and processing of municipal solid waste. Publishing house of FSBEI HPE "TSTU", 2015.

[2] Abdullin, T.M. Educational laboratorial facility for researching the technology of plasma gasification of production and consumption wastes including medical wastes / T.M. Abdullin, I.R. Gilmanshin, N.F. Kashapov, S.I. Gilmanshina, A.I. Galeeva, D.R. Krainova // IOP Conference Series: Materials Science and Engineering Volume 412, Issue 1, 23 October 2018, #012001

[3] Federal Law of December 30, 2009 No. 384-ФЗ “Technical Regulations on the Safety of Buildings and Structures”

[4] Ershov A. G., Shubnikov V. L. Thermal disposal of waste: theory and practice, myths and legends. MSW Journal. 2014. No. 5. P. 47 - 52.

[5] Federal Law of January 10, 2002 No. 7-FZ “On Environmental Protection”

[6] Bilitiewski B. Waste incineration: German experience. Municipal solid waste. 2007. No. 1. From 47 - 49.

[7] Federal Law of March 30, 1999 No. 52-FZ “On the Sanitary and Epidemiological Well-Being of the Population”

[8] Federal Law of November 23, 2009 No. 261-ФЗ “On Energy Saving and on Improving Energy Efficiency and on Amending Certain Legislative Acts of the Russian Federation”
[9] Gilmanshin I.R. Energy utilization of landfill gas as a way to form a new model of waste management / I.R. Gilmanshin, N.F. Kashapov, S.I. Gilmanshina // Problems and prospects of innovative development of the economy: Materials of the scientific forum (XXI international scientific and practical conference), Alushta, September 19-24, 2016 Simferopol: Scientific and Technical Union of Crimea; Moscow: EkOOnis Publishing House - 2016. - 264 p.

[10] Kozhinov V.F., Kozhinov I.V. Ozonation of water. M., Stroyizdat, 1974.

[11] Abdullin T.M. A technique for researching the technology of plasma gasification of medical waste and production and consumption waste / Gilmanshin I. R., Kashapov N. F., Gilmanshina S. I., Krainova D. R. // Materials of the IX International Scientific and Technical Conference “Innovative Engineering Technologies, equipment and materials - 2018 ”(ISTC “IMTOM-2018 ”). Part 1. - Kazan, 2018.-- 237-241 p.

[12] Bernadiner M. N., Bernadiner I. M. High-temperature processing and disposal of liquid, paste-like and solid industrial and medical wastes. Ecology and industry of Russia. 2011. April. From 19 - 21.

[13] Gilmanshin I.R. Study of projects for the rehabilitation of landfills for production and consumption waste in terms of the organization of energy utilization of landfill gas / I.R. Gilmanshin, N.F. Kashapov, S.I. Gilmanshina, A.I. Galeeva, L.S. Sabitov // Materials of the VIII International Scientific and Technical Conference “Innovative Engineering Technologies, Equipment and Materials - 2017” (ISTC “IMTOM-2017”). Part 1. - Kazan: Foliant Publishing House - 2017. - P. 220-224.

[14] Abdullin T.M., Gilmanshin I.R., Kashapov N.F., Sabirzyanov R.G., Gilmanshina S.I., Galeeva A.I. and Gadirova E.M. 2019 About waste disposal problem in Russian Federation. IOP Conf. Series: Materials Science and Engineering570 (2019) 012001

[15] Vasilyak L.M. The use of flash lamps for disinfection // Electronic processing of materials. - 2009. - No. 1. - P. 30-40

[16] Voronov A. New generation of low pressure mercury lamps for producing ozone // Proceedings of World congress on ozone and UV technologies. - LA, California, USA. - 2007.-- P. 2166 -2172.