Plasma Technology and equipment for medical waste processing

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Abstract: Over the past decades RF plasma technology has been used in many areas. Most thermal plasma processes are based on inductively coupled plasma (ICP). Non-equilibrium plasma is mostly used in the semiconductor industry and for some special applications, such as plasma synthesis of fine powder and bio-material surface treatment. We will focus on the present situation in this field by discussing the commercial and R&D efforts related to RF plasma technology for toxic medical waste processing.

Keywords: plasma, medical, waste, toxic, treatment

1. Introduction

The issue of medical waste disposal was, until recently, considered of little relevance for many countries, which coincided with the global assessment of its importance. However, since the end of the last century, interest and a variety of approaches to this problem, especially in highly developed countries (USA, Israel, Japan, Germany, etc.), have increased significantly. It is believed that this is due to the strategic trend declared at the international level towards a comprehensive "greening" of the environment, as a factor that compensates for its degradation due to industrial development and also with an increase in the specific danger to the population from the rapidly accumulating volumes of highly toxic and infected waste from hospitals and biomedical industries. And also the medical waste generated during the pandemic. Some countries did not pay attention to medical waste processing due to the small volume of medical wastes compared to industrial, household, and municipal. For example, according to the data of 2000, about 37 million tons of non-recyclable waste from the chemical industry was accumulated annually, including 200 thousand tons from the petrochemical industry. The need for the annual disposal of hazardous waste of medical origin was approximately 20 tons. However, sanitary and hygienic studies of typical solid medical waste [6], show that their danger to the environment is significantly higher than that of most chemical wastes (with the exception of only those containing substances of the 1st hazard class according to the toxicological classification) and, for example, in the case of solid waste containing cytostatic drugs, antibiotics and others, comparable to the danger of contamination with radioactive waste of high and medium level of activity (> 10 Bq / kg). The problem under consideration is complicated by the fact that the already accumulated and stored solid medical waste, as a rule, is not sorted and in some cases has a very complex composition that cannot be accurately identified. At the same time, the standards adopted for the processing of medical waste in Japan, Italy and other countries [7] require preliminary sorting of them into groups, depending on the composition. So, there are four main groups:

1) ordinary (biochemically stable) and environmentally friendly waste, which can be disposed of in open landfills (together with household waste) even without additional soil backfill.
2) slightly hazardous, but chemically unstable waste, which, due to decomposition during storage, can emit harmful substances, therefore, they must be disposed of in landfills with an anti-seepage lining and with a special system for collecting and processing wastewater.
3) highly hazardous waste requiring special treatment and subsequent disposal (for example, in Japan, all medical waste containing radionuclides is collected and processed by the Japanese Isotope Society).
4) medical syringes, which are recommended to be collected and recycled separately from other waste.

Obviously, in the case of processing unsorted waste, it will be necessary to use the most universal methods, i.e. guaranteeing disinfection and neutralization of any waste components.

1. Technologies and methods of toxic medical waste recycling

In the technology of processing this type of medical waste, the main conventional methods are thermal, in particular, using fuel or plasma furnaces for combustion in an oxygen-containing environment or pyrolysis in a reducing atmosphere to obtain H_2 and CO, which can be further used as synthesis gas for chemical industry or as a fuel mixture. Moreover, direct combustion or pyrolysis of the initial solid waste, providing gasification of its inorganic components, is usually only the first of three stages of the overall technological process. At the second stage, the gas products of the first stage are brought to a given composition and it is carried out in a special afterburner; at the third stage, the non-gasified inorganic residue is ash, the formation of which, according to [8] is up to 20% of the mass of unsorted medical waste, introduced into the furnace. The latter stage can be carried out by melting the ash to obtain a crystalline material to be buried, or by obtaining vitrified ingots having a higher chemical resistance. The vitrification process requires various additives (iron and silicon dioxide), which makes it possible to obtain silicate materials, from which, when stored in ordinary soils, there is practically no leakage of heavy metal ions, and the rate of their leaching does not exceed 10^{-9} to 10^{-10} kg / (m^2 sec).

The most promising version of this technology, actively developed in the USA, Germany and Japan in the last 4-6 years (Westinghouse, Plasma Energy Corporation (USA), NUKEM and Siemens (Germany), Prometron (Japan) , Laboratory INEL (USA), etc.), is the use of shaft-type electric arc plasma furnaces. In this case, compared with non-plasma furnaces, even using intensive gas-dynamic processing (pseudo-fluidized bed, etc.), a number of significant advantages are achieved.The combined factors of a reduction of the furnace volume by 6-8 times (while maintaining the volume and flow of raw materials), a corresponding decrease in the area of production systems, a decrease in the volume of exhaust gases by about an order of magnitude and an increase in the temperature in the reaction zone of the furnace to 1800-2000 K, make it possible to improve the density of the ash residue and to exclude the formation of toxic components in the gas phase – Cl_2, dioxins and polychlorinated biphenyls.

In this work the collection and analysis of information on the qualitative and quantitative composition of biomedical waste has been carried out, technologies for the processing and disposal of biomedical waste by various methods have been considered, a plasma recycling technology has been described, and a model for the process of high-temperature biomedical waste processing has been selected. Also, a thermodynamic analysis of the plasma thermal processing of liquid medical and biological waste and waste generated in pharmacological production was carried out, a model of an experimental installation was developed and plasma system designed and manufactured, and a method for conducting experimental research was chosen. Experiments were also carried out to process samples of real liquid waste from the production of medical products obtained during scientific and technical cooperation with medical institutions. The analysis of the exhaust gas phase and the analysis of the remainder of the liquid fraction of each of the samples, which remained in the reactor after treatment, were carried out. The obtained optical spectra were decoded. An experiment was carried out, the purpose of which was to refine the treatment of medical waste and analyze the resulting products. A mixture of ethyl and isopropyl alcohols and acetone in various ratios was used as a raw material. This mixture is a real production waste that is generated during the cleaning of containers in pharmacological industries. These are liquids produced by mexibel: TP-1, TP-2, TP-3 and TP-4, from the stage of obtaining the substance of sodium levothyroxine; During the experiments, with the given parameters of the plasma reactor in operation, the percentages of gases H_2, CO, CO_2, CH_4 were measured using a combined gas analyzer along with the temperature measurement of the exhaust gas (T_1 is the temperature at the outlet of the reactor, T_2 is the temperature at the outlet of the afterburner). The operating modes of the reactor and the results of the experiments performed are shown in Fig. 1.

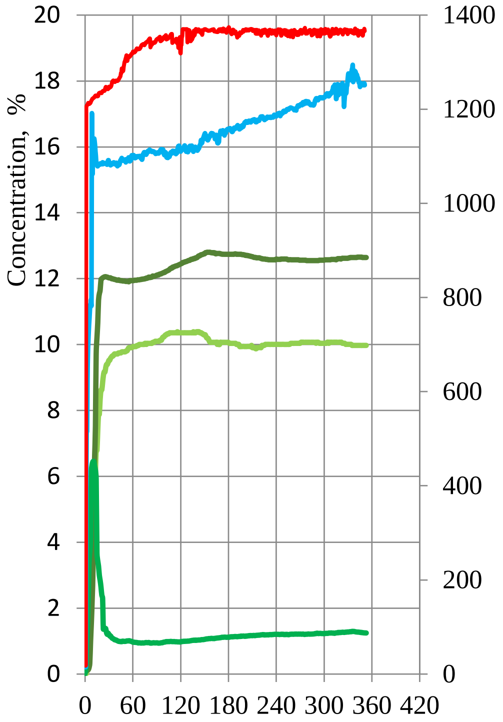

Fig. 1 Concentration and temperature (Celsius) vs time (in seconds). Red- T_1; Blue -T_2: Grey- CO; Light green – H_2; Dark green – CO_2

The decoding of the obtained spectra was carried out and it was found that the qualitative composition of the liquid fraction is identical to the loaded material. Thus, it can be concluded that the synthesis of secondary toxic substances does not occur in the reactor.

The analysis of the composition of waste gases such as Cl_2, cyanides and undecomposed chlorine-containing organic substances was carried out using a RAID-S2 ion spectrometer. These substances were not found in the exhaust gases. Similar results were obtained and presented in [1], where it is shown that the plasma-thermal technology for waste processing is universal, because it can be used for the disposal of any waste regardless of its composition and preliminary sorting.

2. Plasma pyrolysis – efficient method for processing of COVID-19 medical waste

COVID-19 has led to a huge increase in medical waste around the world, mostly generated in hospitals, clinics and other healthcare facilities [1]. This poses an additional challenge in the management of medical waste, especially in developing countries. Improper handling of medical waste can cause serious public health problems and have a significant impact on the environment. There are currently three disinfection technologies available for the treatment of COVID-19 (CMW) medical waste, namely incineration, chemical and physical recycling. We focus on thermochemical processes, in particular the pyrolysis process for the treatment of CMW. Pyrolysis is a process that takes advantage of the instability of organic components in medical waste to convert them into valuable products. In addition, the technology is environmentally friendly and more efficient, requires less disposal capacity, causes less pollution and is more cost-effective. The current pandemic situation is generating a large amount of plastic medical waste, which contains components such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and nylon (N). This plastic waste can be converted into valuable energy products such as oil and gas. This study provides information on the handling of CMW, processing methods, the production of valuable products (biofuels) and proper discharge into the open environment. The origin of the new human coronavirus (SARS-CoV-2) and its potential danger have increased the amount of face masks and medical waste in the environment, requiring urgent measures to prevent and control the pandemic. As it is shown in [1-3], the generation of face masks and medical waste in different countries during a pandemic is assessed in order to convince waste management authorities and the scientific community to find ways to eliminate the negative impact that waste disposal has on the environment. Standartization, procedures, guidelines and strict adherence to the management of COVID-19-related medical waste in public places must be carefully considered to reduce the risks of a pandemic in hospitals, as proper disposal of medical waste effectively controls sources of infection. Currently, in connection with the coronavirus pandemic, the most acute problem is the safe disposal of masks and gloves. Within the framework of the legislation of most countries, during the collection, disposal and temporary storage of waste in medical institutions, all medical waste must be disposed of using methods that are safe for the environment. To solve this problem, plasma technology is the most optimal technology in terms of safety, productivity and energy efficiency [2]. A set of tests was carried out on a plasma installation to find optimal technological solutions. Parameters such as the composition of the exhaust gases, its dependence on temperature in the chambers of the plasma-arc reactor, and the specific energy consumption have been determined. The need to obtain these parameters is associated with the further development of installations with a capacity of 50 kg/Hr and more. Experimentally obtained optimal temperature range is 1200 – 1300 ^{0}C. Chemical composition of the exhaust gases is shown on Fig.2.

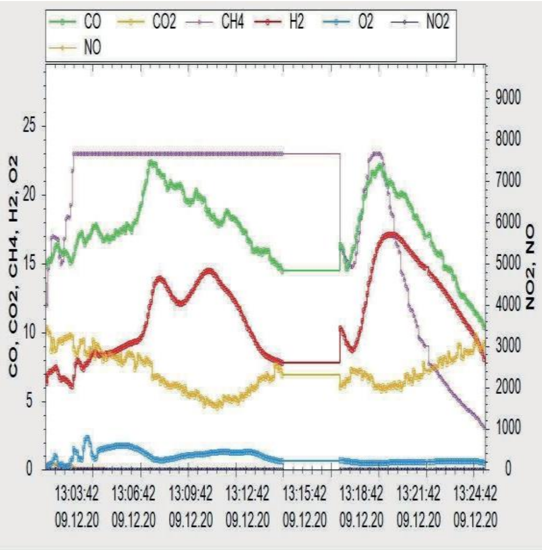

Fig. 2 Chemical composition (%wt.) of off gases at average plasma temperature of 1200 to 1300 ° C.

The chemical composition of the gas generated at the high temperature in the plasma reactor is the best in terms of productivity and composition of the gases formed. When the temperature rises to 1200-1300 ° C in a plasma-arc furnace, the elemental composition of the exhaust gases is: CO_2-4.5%, O_2-0.5%, CO- 22%, H_2-14.5%, NO-0 ppm, NO_2-0 ppm. According to experimental data, the gas contains no nitrogen oxides and dioxides, and also a low carbon dioxide content. The peaks in the graph shown in Figure 2 are associated with the discrete feeding of packaged waste. Comparison of calculated and experimental data for the process of high-temperature gasification of organic waste shows good convergence.

Thus, the goal of the work was achieved, namely: determination of optimal technological parameters for the composition of exhaust gases, the dependence of exhaust gases on temperature in a plasma-arc furnace, the specific energy consumption in the technological process, and temperature conditions. for disposal of medical waste before their complete decomposition into simple chemical compounds. At the same time, there are no harmful components in the exhaust gases. Our experimental studies [4,5] also made it possible to establish the possibility and feasibility of implementing plasma technology for medical waste treatment.

4. References

[1] Salvakumar Dharmaraj et al. Pyrolysis: An effective technique for degradation of COVID-19 medical wastes / Chemistry, N7, 2022.

[2] Samuel Jacob, Sajesh Nitianandam, Shresta Rastogi / Strategies for the Treatment and Treatment of SARS-CoV-2 Contaminated Biomedical Waste and Biological Solids in the Waste Environment, In the book: Environmental and Health Management in Novel Coronavirus Disease (COVID-19), January 2021.10.1016 / B978-0-323-85780-2.00012-3

[3] P V Domarov, AS Anshakov, and V A Faleev Electroplasma processing of medical and biological waste J. Phys .: Conf. Ser. 2119 012039

[4] Messerle V.E., Mosse A.L., Nikonchuk A.N., Ustimenko A.B. Plasma-chemical processing of medical and biological waste. Engineering Physics Journal. - 2015. - T.88, No. 6, p.1420-1425.

[5] A.N. Nikanchuk, A.L. Mosse, V.V. Sauchyn, A.V. Lozhachnik Design and investigation of plasma chamber furnace for bio-medical waste processing. / 6 International Conference Plasma Physics and Plasma Technology, Minsk, Belarus 2009. p. 684-687.

[6] Brunner CR, Brown CH / Journ. Air Pollut. Contr. Assoc. 1988. V.38, N 10, p.1297

[7] Briosi GL, Ventola G. / Termotecnica. - 1989. - V. 43, N 12. - P.49; Tanaka, M. / Kogykenkyu. - 1989. V. 18, N 4. p.45.

[8] Proceedings of the 2nd International Symposium on Plasma Chemistry, Ivanovo , Russia, 1995, p. 387