Improving the efficiency of energy output from landfill gas by controlling the morphological composition of MSW

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Abstract. The change of the elemental composition and increase of the amount of waste, in particular MSW, is urgent environmental and socio-economical problem for Russia today. The main part of MSW is transported to landfills and utilized by inefficient or environmentally unsuitable disposal methods.

The compromise between economic development and environmental conservation is one of the most discussed problems of modern economics and sustainable development of our society. The morphological composition of MSW changes annually due to the growth and changes in the needs of human and industrial waste, and varies depending on the locality.

Mixed MSW are waste that is hazardous to human health, as they are characterized as a multicomponent system, whose components have a complex chemical composition. The presence in the MSW of organic fractions (food, plant, etc.), as well as the content of hazardous type 1 and type 2 materials (“hazardous waste”) in them, cause the possibility of the appearance of various diseases due to the ingress of toxic components into the soil and groundwater. [3]

There are 3835 thousand tons of MSW formed annually in Moscow and the Moscow region. The morphological composition of the MSW of the Moscow region and the average morphological composition of the MSW in the world are presented in Fig. 1 and 2. [5]

Figure 1. Morphological composition of MSW in the Moscow region, % [2]
Figure 2. The average morphological composition of MSW in the world, % [2]

| Table 1. Factors affecting the component composition of MSW, [2] |
|---------------------------------------------------------------|
| **Factor** | **Influence** |
| **Temporary** | |
| Stage | The structure of the consumption of goods is subject to constant changes (the emergence of new types of products, packaging, etc.) |
| Season | In the autumn, as a rule, the content of food waste increases, the specific formation of waste per person in different seasons is also uneven. |
| Day of the week | The composition of waste on weekends and holidays may differ significantly from that on weekdays. |
| **Territorial** | |
| Climate | The climatic conditions of the area determine the structure of food grown on-site and, accordingly, their consumption. |
| Transport accessibility | The development of a transportation access with other territories is reflected on the used goods. |
| **Socio-economic** | |
| Wastewater | Waste of the population is significantly different in composition from waste infrastructure |
| Population structure | Waste from a population with different income levels and employment, have different component composition |
| Degree of household improvement | Availability of furnace heating, garbage chute, number of storeys affect waste composition |
| Development of the market of secondary raw materials | The developed market of secondary raw materials helps to reduce the content of useful components in the waste. |
| **Sanitary** | |
| Wastecollection system | The presence or absence of separate collection directly affects the composition of the MSW |
| Frequency of export | Waste composition changes during the week. With prolonged storage of waste, it is possible that they become wet, bloat, and the like. |
| Prospects for the development of waste management systems | Existence of a waste management strategy and concept implying a change in the waste management system, such as a waste collection system |
MSW includes cardboard, plain paper, leather and rubber, stones, glass and metal, textiles, food waste, wood, polymers and etc. Plastic waste does not decompose for a long time and that’s why it is a particular hazard. Rotting communal garbage is the main component for the production of pathogens. Chemicals from the MSW are released into the atmosphere cause allergic, toxic, endocrine diseases. [3, 9, 11]

The number of landfills and unauthorized landfills in Russia is growing every year, occupying more and more areas, creating a bacteriological threat by polluting groundwater, creating a threat to air traffic, attracting large flocks of birds. Also, the formation of landfill gas in large quantities can lead to self-ignition of waste, and harmful compounds (SO2, etc.), which are part of it, poison the environment. [7, 8, 10]

The composition of MSW includes hazardous and toxic substances that threaten human life and health, and since the most part of the waste does not process the sorting, the recycling process must occur through special methods of thermal destruction.

Recycling and disposal of waste is one of the most pressing and requiring special attention problems not only in our country, but throughout the world [8]. This mainly applies to large and rapidly developing densely populated cities, where a huge amount of municipal solid waste (MSW) accumulates. Each year, 140 million cubic meters of MSW accumulate in our country, of which only 3% is recycled, which is unacceptable. The rest of the waste is transported to special landfills for disposal, or to landfills. A distinctive feature of the MSW is that they contain a high percentage of the combustible component contained in such components as rubber, paper, slag, wood, etc. In this regard, people began to think about using waste as an energy source. This idea is the solution to the two most common problems of our time: energy generation and waste disposal. Of course, burning MSW has not only advantages, but also significant negative consequences, difficulties in implementation. The main methods of thermal destruction of waste are incineration, pyrolysis and gasification.

Humidity of waste directly affects the amount of electricity consumed during the process of utilization by thermal methods; therefore, it is necessary to pre-dry the waste to reduce losses.

**Table 2.** Harmful substances generated during the combustion of MSW. [12]

| Substance     | mg / m |
|---------------|--------|
| Flyash, dust  | 5000   |
| NOx           | 210    |
| SO2           | 280    |
| CO            | 50     |
| HCl           | -      |
| Cd, Tl        | 0.5    |
| Hg            | 0.06   |
| Pb, Co, Cr, Ni, As, Sn, Bi | 60 |
| Dioxins       | $2 \times 10^6$ |

**Table 3.** Comparison of the main thermal methods of disposal of MSW. [4]

|                  | Burning 650 ºC | Pyrolysis 450-900 ºC | Plasmagasification 2000 ºC |
|------------------|----------------|----------------------|---------------------------|
| Power destruction| 70%            | 90%                  | 99%                       |
| The presence of tar and furans | Lot | thereis | Not |
| Ash and toxic | 30% toxic | 10% ash | Not |
One of the main ways to utilize MSW in the world is to bury it at the close distance area. Under these conditions, waste is subjected to intensive biochemical decomposition with the formation of landfill gas (biogas) [12], which leads to environmental problems. The main components of biogas include not only greenhouse gases (methane and carbon dioxide), but also such toxic compounds as carbon monoxide, nitrogen oxides, hydrogen sulfide, sulfur dioxide. In the process of thermal effects and ignition of waste, carcinogenic compounds benzene and benzapyrene are released. The emission of landfill gases entering the environment has negative effects of both local and global geocological nature.

Biogas is formed as a result of the anaerobic decomposition of the organic fraction of waste and is 98% composed of methane and carbon dioxide [12]. Of the total amount of methane entering the atmosphere annually, 40-70% is formed as a result of anthropogenic activity, and more than 20% of them are accounted for MSW disposal facilities. It is estimated that about 200 m³ of biogas is produced from one ton of MSW. At the same time, for the first 15–20 years, when one ton of MSW is decomposed, up to 7.5 m³ of biogas is released per year. In the future, the intensity of biogas emission is sharply reduced. The dependence of the specific biogas yield for the period of its active stabilized generation is described by the formula:

$$Q = \frac{1.35G_0(1 - 10^{kt})}{\left(\frac{59 - W}{13}\right)^4}$$

Organic fractions of MSW are characterized by different periods of decomposition and intensity of methanogenesis. Under these conditions, the qualitative composition of landfill gas acquires a variable, stochastic nature. Existing technologies for utilization of landfill gas are quite sensitive to the stability of the quantitative and qualitative characteristics of landfill gas as fuel. Therefore, experimental methods for determining the specific heat of landfill gas are needed. The work on determining the characteristics of landfill gas as a hydrocarbon fuel of variable composition is carried out jointly by Professor V. Larionov. Experimental determination of the specific heat of combustion of gaseous hydrocarbon fuel is carried out using a diffusion combustion tube of the fuel-air mixture in an air stream.
Figure 3. Diffusion combustion tube of the fuel-air mixture in an air stream
The proposed method will allow to determine the dependence of the energy potential of landfill gas on the morphological composition of MSW

Literature

[1] Zilenina VG, Ulanova O V 2017 The study of the composition of hazardous solid municipal waste (for example hit) Healthy environment - the basis of regional security. Materials of the first international environmental forum in Ryazan pp 43-49

[2] VI Vorobev, GP Timofeev, VV Charnetsky 2018 Morphological composition of municipal solid waste Science of the Young is the Future of Russia collection of scientific articles of the 3rd International Scientific Conference of Advanced Developments of Young Scientists: in 6 t. pp 162-68

[3] OD Dnipro, NAKirichenko, D A Solov' ev 2018 Garbage as a socio-philosophical problem Days of Science Materials of the interuniversity scientific and technical conference of students and cadets on the basis of Kaliningrad State Technical University pp 218-22

[4] R G Sabirzyanov, IR Gilmanshin, NF Kashapov, SI Gilmanshina, DR Kraynova 2018 Thermal destruction of production and consumption waste Proceedings of the IX International Scientific and Technical Conference "Innovative machine-building technologies, equipment and materials - 2018" (ISTC "IMTOM-2018") pp 242-46

[5] Popov V M 2012 Disposal of production and consumption waste Kursk

[6] IR Gilmanshin, NF Kashapov, SI Gilmanshina 2016 Energy disposal of landfill gas as a way to form a new model of waste management Problems and Prospects of Innovative Development of the Economy: Materials of the Scientific Forum (XXI International Scientific and Practical Conference) 264 p

[7] I R Gilmanshin, NF Kashapov, S I Gilmanshina, AI Galeeva, LS Sabitov 2017 Study of projects for the recultivation of landfills for production and consumption in terms of the organization of landfill gas energy utilization Proceedings of the VIII International Scientific and Technical Conference "Innovative machine-building technologies, equipment and materials - 2017" (MNTK "IMTOM-2017"). Part 1 pp. 220-224

[8] NF Kashapov, NN Nafikov, IR Gilmanshin, AR Nigmatzyanov, VYa Petrova 2017 Recycling of agricultural production and rural settlements with the production of biogas and organic matter Innovative machine-building technologies, equipment and materials - 2017 Materials of the VIII International Scientific and Technical Conference pp 255-59

[9] IR Gilshmanshin, NF Kashapov, AI Galeeva 2016 Energy utilization of landfill gas from landfill gas as a way to form a new model of waste management Problems and Prospects of Innovative Development of the Economy: Proceedings of the Intern. scientific and practical conf. pp 238-42

[10] Manelis G B 2001 Energy and Ecology, Institute of Problems of Chemical Physics RAS. Chernogolovka

[11] Petrov V Vand others 2012 Ensuring the functioning of the urban system of environmental monitoring of waste management data production and consumption in the city of Taganrog Engineering Bulletin of the Don V 23 No. 4-2
[12] Bespalov VI, Adamyan RG 2013 Assessment of the conditions of the landfills disposal for the solid waste utilization Journal “European Applied Sciences” V 2 pp 190-94