ALTERNATIVE FUEL SOURCES – A PERSPECTIVE WAY OF ENERGY-SAVING

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The review of technologies of extraction and use of an alternative source of "blue" fuel – landfill gas on dumping sites and sanitary landfills has been carried. The data of working plants is resulted. The perspectives of landfill gas extraction and utilization in Russia are observed. The method of mathematical modelling of the processes proceeding in a body of sanitary landfills is described, allowing theoretically determining of methane potential at each stage of its life cycle.

INTRODUCTION

The mankind needs energy, and needs for it is increasing every year. At the same time, resources of traditional natural fuels (oil, coal, gas and etc.) are nonrenewable. Total consumption of thermal energy in the world today is 200 billion kwh per year, (it is 36 billion tons of equivalent fuel). The general consumption of fuel in modern Russia averages about 5 % of a world power balance [6]. Over 80 % of all geological resources of organic fuel in the world falls to the share of coal which becomes less popular due to its harmful influence on environment. Besides under forecasts of some experts the coal resources will be exhausted by 2100 year. Already now the oil and gas extraction is appreciably reduced, but not due to modernization of technologies of oil and gas refining, but due to an exhaustion of natural resources. Thus, by 2020 year the share of oil and gas recovery in the world fuel and energy balance will decrease from 66,6 % to 20 %. Hydro- and wind energy makes only 2,3 % of energy generation in the world and can play only an auxiliary role because of essential disadvantages: needs for equal platforms of significant sizes, necessity of their withdrawal from economic circulation and changing of a habitual natural landscape, also acoustic noise and vibration of ground. Thus, neither organic fuel nor hydro- and wind energy can solve problems of power engineering in long-range outlook. Nuclear fuel resources – uranium and thorium from which it is possible to receive in reactors plutonium – are also reduced. The basic disadvantages of the given way of producing of energy are the problems of high reliability of nuclear power-generating units and atomic power stations price rising. Stocks of thermonuclear fuel – the hydrogen are practically inexhaustible. However, controlled thermonuclear reactions are not mastered yet and it is not known, when they will be used for industrial reception of energy.

Thus, the considered ways of production of energy cannot solve the problem of power supply of the future generations. There are two ways left: severe economic power resources consumption and use of renewable power sources. Renewable power sources represent today real alternative to traditional technologies and are the most perspective from the point of view of preservation of natural environment and primary natural resources. To such sources we can relate the introduction of technologies of biodecomposition of waste products of an organic origin (waste products of cattle-breeding and poultry-farm complexes and etc.), burning of *municipal solid waste* (MSW) with the use of heat of smoke fumes, and also use of *landfill gas* (LG) formed on sanitary landfills. The greatest interest represents the reception of LG since a number of problems of economical and ecological character are solved.

Macrocomponents of LG are methane (CH_4) and carbon dioxide (CO_2), their parity can vary from 40-70 % up to 30-60 % accordingly. An accompanied components of LG are nitrogen (N_2), oxygen (O_2), hydrogen (H_2) and various organic compounds[5]. Emissions of LG in natural environment form negative effects both local and global character. So, for example, in the USA the law of the necessity of the equipment of all, without exception, sanitary landfills of the country by systems of extraction and neutralization of LG has come into force after the American researchers had shown that dumps are the basic anthropogenic source of methane in the USA. It is interesting to note, that the essential contribution to global emission of LG is made by Russia. According to the Intergovernmental Panel on Climate Change (IPCC) estimation dumps of Russia annually throw out 1,5 million tons of LG in an atmosphere, that makes approximately 3 % from a planetary stream [1].

The organic substance, being the basic component of MSW, decays on dumps approximately within 20 years. An active formation of gas in a thickness of storage of wastes begins approximately to the third year from the beginning of warehousing, gradually accumulates, and proceeds for 10-15 years, and then process is gradually slowed down. Therefore at an average landfill gas output of 100 m^3/t of MSW average speed of its output is accepted, usually, 5 m^3/t of MSW per year. This figure proves to be true by the field data of 86 systems of landfill gas gathering in different countries [4].

LG formed on dumping sites, without preliminary clearing we can use as fuel for boilers and furnaces, i.e. it can be delivered directly to the industrial consumer for reception of heat or for use in any technological process (roasting, technological pair reception and etc.). This way of use of gas is the most effective on the assumption of its continuous consumption [7].

LG is also used after preliminary clearing for reception of the electric power with the help of combined heat and electric power manufacturing plants. The produced electricity can be used directly on a platform of a dump or moved to power circuit.

In the long term we can use LG after its enrichment to a natural gas quality. At the process of gas enrichment it is dried up, carbon dioxide and other impurities are moved away. However, systems of improvement of LG quality are very expensive and do not find wide application nowadays [2].

Leaders of annual extraction of gas from MSW in the world are: the USA – 500 million m^3 per year, Germany – 400 million m^3 per year, the Great Britain – 200 million m^3 per year. On the whole, global extraction of LG is approximately 1,2 billion m^3 per year, that is equivalent to 429 thousand tons of methane or 1 % of its global emission [3].

Special technical and economic calculations of possible typical objects of extraction and utilization of gas from dumping sites were carried out in Russia. Two variants of technological circuits of gas utilization were considered: manufacture of electric power and gas delivery to consumer. In result, they have established, that objects of electric power manufacture demand big investments and are more profitable on absolute parameters; all technical and economic parameters of the objects proportionally grow with the growth of weight of landfill bodies; all considered variants are economically effective.

On the basis of the received data the project "The sanitary landfill with energy regeneration in territory of the Moscow area" has been developed and introduced. The basic purpose of the project was demonstration of opportunities of biogas technology in Russia.

Two typical sanitary landfills of the Moscow area have been chosen as objects: sanitary landfill "Dashkovka" in the Serpukhov area and sanitary landfill "Kargashino" in the Mytishchinsk area.

The variant of recycling of biogas in a mode of production of electric power has been chosen. Systems of gas extraction, including holes, gas-mains and compressor stations, providing gas rendering to motor-generators, situated near to sanitary landfills, have been constructed for this purpose in these territories.

The experimental-industrial mode of tests has shown the manufacture up to 80 kwh of electric power on each sanitary landfill. Thus, in the Russian conditions from 1 m^3 of LG we can produce 1,3-1,5 kw of the electric power. It means, that with the full use of LG resources on dumping sites it can be made about 500 megawatt of electric power per year [2].

The conducted analysis of existing situation of LG use in the world has shown, that the tendency of expansion of gathering and utilization of LG, formed on dumping sites, is observed in many countries, but the volume of extractive gas is insignificant in comparison with the volume of its formation. This fact opens large-scale opportunities for LG use as an alternative source of "blue" fuel.

MATERIALS AND METHODS

The developed method of mathematical modelling of the processes proceeding in a body of a dump, has allowed defining theoretically methane potential of a sanitary landfill at each stage of its life cycle.

The methane potential is the quantity of methane allocated by a mass unit of waste products of the given morphological structure.

The following parameters are accepted as the initial data for forecasting emissions of methane from sanitary landfills:

- morphological and chemical composition of biodecomposing part of MSW;
- ash content of waste products, A;
- moisture, w;
- factor of biodecomposition of waste products at the stage of complete formation of methane Bf (depends on morphological structure of biodecomposing part of MSW).

Full potential of generation of methane L_o (normal м^3 per ton (nm^3/t) of dry waste products) can be expressed as:

$$L_0 = \sum \left(L_{0i} \cdot x_i\right), \quad (1)$$

where x_i – mass share of biodecomposed fraction;

L_{oi} – the methane potential (nм^3/t of dry waste products) for each fraction of waste products with the account of the factor of biodecomposition B_f and ash content of waste products A.

L_{oi} can be expressed as:

$$L_{0i} = 11088 \cdot \frac{n_c}{\mu_i} \cdot (1 - A) \cdot B_f, \quad (2)$$

where n_c – kilomole number of carbon, contained in one ton of the fraction;

μ_i – molar weight of the fraction, kg/kilomole.

The quantity of methane Q (nм^3), allocated under the time τ, is defined as follows:

$$\frac{dQ}{d\tau} = (L_0 \cdot M_c - Q) \cdot k, \quad (3)$$

where L_o – methane potential of waste products, nм^3/t;

$k=1/\tau$ – a speed constant of decomposition;

M_c – weight of dry waste products, t.

M_c can be expressed as:

$$M_c = (1 - w) \cdot M_{вл}, \quad (4)$$

where $M_{вл}$ – weight of moist waste products, t.

RESULTS

Having carried out corresponding mathematical operations, the formulas for definition of allocated methane volume and speed of its formation are deduced.

The incorporated theory was the base for experimental researches in the laboratory. The morphological structure of waste products loaded to the bioreactor is submitted in table 1. Experiments were carried out for 30 days. The gas phase formed during biodecomposition contains (in mg/m^3): methane – 6,74; ammonia – 9,0; hydrogen sulphide – 0,0245; phenol – 0,035; mercaptan – 0,067.

Discussion

Calculated and experimental values of volumes of allocated gas are submitted on figure 1.

Regression analysis of the received results has shown the coincidence of calculated and experimental data with the correlation coefficient r=0,996.

Table 1

Calculation of methane potential

The name of waste products	The contents of components in a mix of waste products, % mass.	Methane potential, liter per kilogram (l/kg)
Food	17,2	0,062
Paper	53,0	0,1279
Landscape-gardening	27,8	0,0889

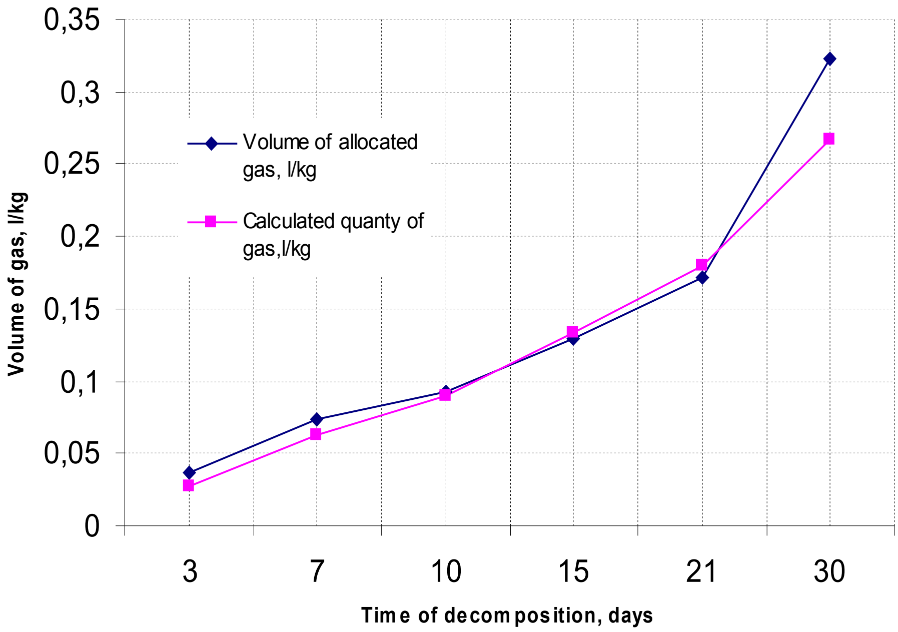

Figure 1. Dynamics of methane formation during laboratory experiments

Thus, reliability of the offered method of an estimation of gas-bearing abilities of sanitary landfills proves to be true by conducted experimental researches. Calculation is made on weight of stored waste products that allows disregarding of density changes of waste products at pilling and during decomposition. The burned part of waste products is also taken into account, which raises accuracy of the forecast.

The model is simple enough. It can be used for the solution of various types of engineering-ecological problems with various landscape conditions of MSW burial and at any stage of their life cycle.

Conclusions:

1. The detailed analysis of existing data of LG formation has shown, that gas use is a perspective alternative to natural energy resources from the point of view of preservation of natural environment and primary natural resources.

2. The method of mathematical modelling of the processes proceeding in a dump body has been worked out, which allows defining theoretically methane potential of a sanitary landfill at each stage of gas life cycle.

3. The experimental data received on the basis of the developed laboratory model of LG reception confirm reliability of the theoretically established mathematical dependences.

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