ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (451)

JANUARY – FEBRUARY 2022

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.
Тираж: 300 экземпляров.
Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 451 (2022), 105-114 ***https://doi.org/10.32014/2022.2518-170X.147***

UDC 620.9, 574, 004.94
IRSTI 27.31, 44.31, 62

Temirbekova M.N.[1*], Temirbekov N.M.[2], Wojcik W.[3], Aliyarova M.B.[1], Elemanova A.A.[1]

[1]Non-profit Joint Stock Company «Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev», Almaty, Kazakhstan;
[2]National Engineering Academy of the Republic of Kazakhstan, Almaty, Kazakhstan;
[3]Department of Electronics and Information Technology, Lublin University of Technology, Lublin, Poland.
E-mail: *m.temirbekova@aues.kz*

THE USE OF ORGANIC FRACTION OF SOLID HOUSEHOLD WASTE TO GENERATE ETHANOL AND BIOGAS USING A SIMULATION MODEL

Abstract. The paper shows the efficiency of collecting and disposing of biogas at a landfill of solid household waste using a biogas plant of a modernized design. Effective solid waste management involves the use of various approaches, technologies and treatment concepts to ensure the protection of public health and the environment. The optimal mode of processes occurring in a biogas plant is determined by computer modeling. The identification of the parameters of a mathematical model for describing the biochemical processes occurring in a biogas plant has been carried out. Two approaches are used to solve the mathematical model: a finite-difference method for solving a system of differential equations and simulation modeling using the Any Logic package. A computer program has been compiled in the algorithmic language C++. Numerous calculations have been carried out, the results of which are presented in the form of graphs and their qualitative picture is consistent with the ongoing processes. The created computer program allows you to make a preliminary forecast of anaerobic fermentation occurring in the bioreactor, depending on the volume of the substrate, methanogenic microorganisms and temperature conditions. Alternative methods such as pretreatment of solid household waste, fermentation, ethanol fermentation and anaerobic digestion attract increased attention. Using these methods, a liquid with alcohol-containing substances was obtained from 1.6 kg of organic fraction of solid household waste from the landfill, in which the percentage of ethyl alcohol was 98%, and ethanol (95%) was also obtained from 2.3 kg of the model fraction of waste. Therefore, solid household waste can be a viable source of energy, not a source of pollution. Thus, the article considers the possibility of using mathematical simulation of biogas, as well as a qualitative experiment from organic fraction residues and their further conversion into ethanol.

Key words: simulation modeling, biogas, ethanol, mathematical modeling, organic fraction of solid household waste, thermal treatment, fermentation, ethanol fermentation.

Introduction. In the modern world, the production of biogas and ethanol from abundant and inexpensive waste, for example, agricultural waste [1-3], solid household and alkaline waste [4, 5], is of great interest. The organic fraction of solid household waste in the midst of these inexpensive substrates abound with abundant cheese with zero resistance. Such a method of solid household disposal as burial has gained worldwide practical distribution in peaceful practice, there is no outcome from the description of waste management in various countries of the world, disposal according to this principle is impractical in our time [6].

Annual solid household waste produced in developing countries contains 40-88% of food waste [8, 10], indicating that the organic fraction of waste mainly consists of starch, lignocellulose, lipids, etc. Starch and lignocelluloses have a high potential for conversion to ethanol, unlike lipids, which cannot be converted to ethanol without pretreatment, and these biodegradable components can also be converted to biogas by anaerobic digestion, mathematical and simulation models are usually used for forecasting. Among the various methods, hydrothermal pretreatment reduces the formation of fermentation inhibitors that are formed due to sugar degradation, in addition, this method is environmentally friendly due to the lack of use of chemical and toxic substances, through this treatment most of the hemicellulose is removed and the availability of the enzyme improves, which is the most important factor for obtaining alcohol-containing substances [11].

Taking into account the world practices of various countries, it is possible to offer several options for collecting and disposing of biogas at the solid waste landfill in Almaty, which is the largest waste disposal site serving the city and surrounding villages. About 13.5 million tons of waste have been accumulated within the landfill, from which 1740 m^3/h of biogas can be collected. In addition to producing ethanol, biogas production is also a very attractive project. For implementation, it is enough to install a biogas plant with overpressure protection and a combined frame-blade design of an anchor-type agitator with an automated electric drive. In this paper, computer programs have been created on the basis of well-known mathematical models and simulation modeling of Any Logic to carry out a preliminary forecast of the process of anaerobic fermentation in biogas plants [12].

Materials and methods. Mathematical model and simulation modeling. According to studies of the morphological composition of Almaty waste, food waste is about 30% [13].

Mathematical and computer modeling using mathematical models are the most effective ways to conduct computational experiments, as they are less expensive compared to field experiments. In the works of L.I. Ruzhinskaya, A.A. Fomenkova, the analysis of known models of anaerobic digestion of organic matter with the production of biogas was carried out. The models that are often used in the literature are shown, where the kinetics of methane fermentation and the parameters of the kinetic process are described. Various models describe the growth and development of a population of microorganisms, the degradation of components and the production of products in an anaerobic bioreactor [14]. There are works related to simulation exponential graphs, modified Gompertz graphs of the process of obtaining biogas from solid waste in anaerobic reactors [15]. Also, models are being created to optimize the process of biogas production, complex models including the kinetics of microflora growth, which take into account various charging mechanisms and time intervals, process temperature and inhibitory effects [16].

Consider the following task [17] for modeling the process of biofuel production from organic household waste:

$$
\begin{aligned}
&\frac{\partial W_i}{\partial t} = -k_i \cdot W_i \cdot f_H(S),\ i = 1,\ldots,M, && W(0) = W_0,\\
&\frac{\partial S}{\partial t} = \gamma \cdot \sum_{i=1}^{M} k_i \cdot W_i \cdot f_H(S) - \rho_M \cdot f_M(S) \cdot \frac{S \cdot B}{K_S + S}, && S(0) = 0,\\
&\frac{\partial P}{\partial t} = Y \cdot (1-\theta) \cdot \rho_M \cdot f_M(S) \cdot \frac{S \cdot B}{K_S + S}, && P(0) = 0,\\
&\frac{\partial B}{\partial t} = \theta \cdot \rho_M \cdot f_M(S) \cdot \frac{S \cdot B}{K_S + S} - K_D \cdot B, && B(0) = B_0,\\
&f_H(S) = \left(1 + \left(\frac{S}{A_H}\right)^{N_H}\right)^{-1}, \quad f_M(S) = \left(1 + \left(\frac{S}{A_M}\right)^{N_M}\right)^{-1}
\end{aligned}
\tag{1}
$$

where

W – is the initial substrate concentration(*g/l*);

S – is the hydrolysis product concentration (*g/l*);

W_i – is the vector components of the various types raw material concentrations;

P – is the total biogas yield, (*g/l*);

k – is the hydrolysis kinetic constant;

k_i – *is* the hydrolysis kinetic constants specific to W_i types;

M – is the number of considered raw material types (in this case 3);

B – is the concentration of the methane microorganisms in biomass;

γ – is the conversion coefficient of the substrate into fatty acids (stoichiometric coefficient);

ρ_M – is the methanogenesis maximum specific rate in the terms of the volatile fatty acid biomass utilization;

K_s – is the half saturation constant in the Monod equation for the methanogenesis intensity; $(1-\Theta)$ - is the substrate fraction used for biogas formation;

Y – is the conversion coefficient of the fatty acids utilization flow to final product yield units (biogas);

K_D- is the decay factor;

$f_H(S)$ and $f_M(S)$ – are describe the hydrolysis reactions inhibition and the microbial fermentation process by fatty acids (acidification).

Qualitative experiment of fractional modules. In this qualitative experiment, fractional models of organic components were used, which were collected in accordance with the approximate chemical composition of solid household waste, as well as a sample with organic components from the landfill of solid household waste of the Joint-Stock Company «Tartyp» in Almaty. The experiment compares the potential of a real sample from a landfill and a combined modular fraction with different composition and mass:

-natural cork from the municipal solid waste landfill in Almaty (1500);

-combined fraction (cellulose - 850g, carbohydrates-900g, lipids-500g).

The experiment consists of the following main stages: preliminary hydrothermal treatment, enzymatic hydrolysis (amylase, glucavamarin, amylosubtilin, cellulase), ethanol fermentation (alcoholic yeast) of the liquid fraction of waste.

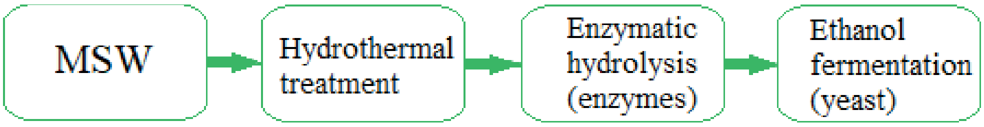

Figure 1. Scheme of the experiment sequence.

Initially, a sample with a different composition is formed, the humidity of each sample is determined, the pH is measured, after the sample undergoes a thermal pretreatment process at 120°C for 4 hours. After hydration, qualitative reactions are carried out for the presence of starch and glucose, the next step is the separation of the sample into liquid and solid fractions and the fermentation process begins. 1.5 g of amylosubtilin is added to the liquid part of the sample for 1.5 hours at 65°C, then 2 g of glucavamorin for 1.5 hours at 50°C. 2 g of cellulase is added to the solid part of the sample for 1.5 h at 50°C and 1.5 g. amylase at 65°C for 1.5 h. After the fermentation process, ethanol fermentation follows, for this purpose alcoholic yeast (15g.) is added to the liquid part to produce ethanol [12].

Results and discussion. Mathematical and simulation models. The values of the constant coefficients used in the model (1) are given in the form of a system-dynamic table in [7]. Using model (1), we built a model in Any Logic. The simulation model and graphs of the main indicators of the process are shown in Fig.1. In Fig.1, through W1, W2, W3, concentrations of feedstock of various types are indicated in the form of vector components W_i.

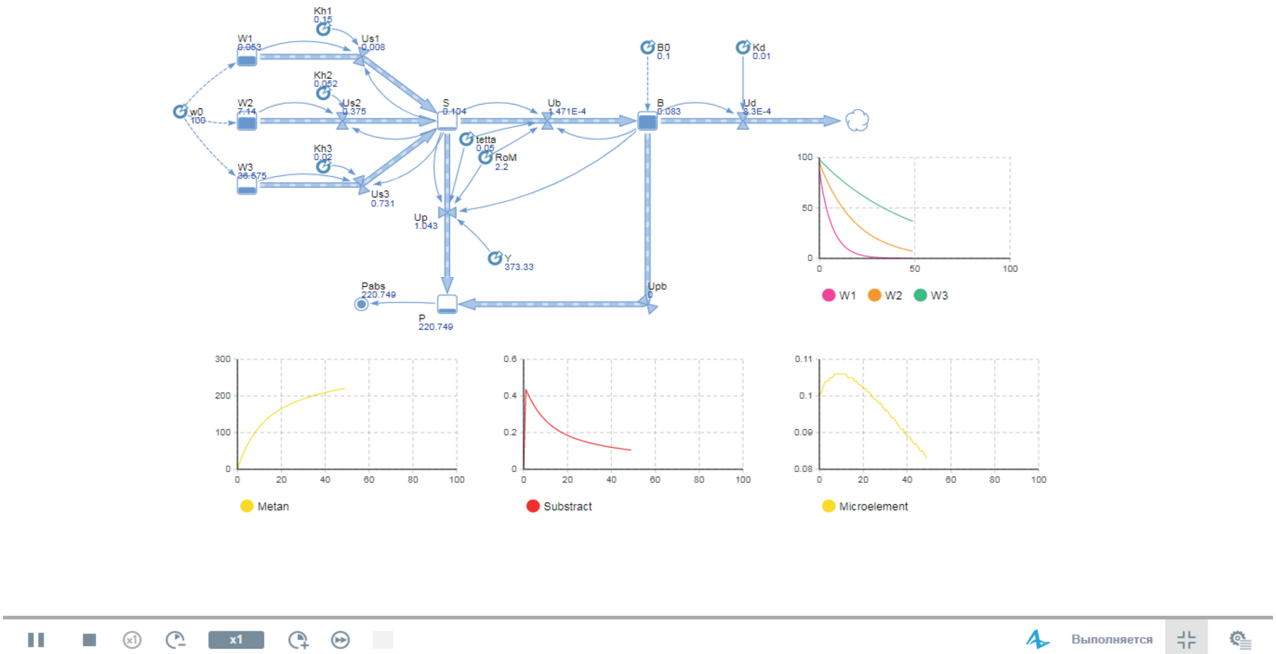

Figure 2. Biogas model in AnyLogic.

When constructing the model, the time unit «days» was selected, since all coefficients are given in the format 1/day. A corresponding semi-implicit difference scheme of the following form is constructed for the system of differential equations (1):

$$W_i^{n+1} = W_i^n - \tau \cdot k_i \cdot W_i^n \cdot f_H\left(S^n\right), \quad i = 1,2,3.$$

$$S^{n+1} = S^n + \tau \cdot \left(\gamma \cdot \sum_{i=1}^{3} k_i \cdot W_i^n \cdot f_H\left(S^n\right) - \rho_M \cdot f_M\left(S^n\right) \cdot \frac{S^n \cdot B^n}{K_S + S^n} \right),$$

$$P^{n+1} = P^n + \tau \cdot \left(Y \cdot (1-\theta) \cdot \rho_M \cdot f_M\left(S^{n+1}\right) \cdot \frac{S^{n+1} \cdot B^n}{K_S + S^{n+1}} \right),$$

$$B^{n+1} = B^n + \tau \cdot \left(\theta \cdot \rho_M \cdot f_M\left(S^{n+1}\right) \cdot \frac{S^{n+1} \cdot B^n}{K_S + S^{n+1}} - K_D B^n \right). \qquad (2)$$

$$n = 1,2,3,\ldots, N$$

For the numerical solution of difference equations, a program has been compiled in the algorithmic language C++. Unknown values of the vector of concentrations of feedstock of various types are set as a one-dimensional array, the concentration of hydrolysis products – the total output of biogas, the concentration of biomass of methanogenic microorganisms in the program are considered as variables depending on discrete time. According to the given values of the initial conditions, the required values are calculated according to the recurrent formulas (2), depending on time. Then the calculated results are imported into a graphical editor and graphs are plotted. A computational experiment was used to identify the coefficients included in the mathematical model. Numerical calculations using the mathematical model (1) can be carried out in a wide range of time steps and equation coefficients satisfying the stability conditions of the difference scheme (2). Therefore, it is necessary to determine the value of the time step corresponding to real time.

By using the initial conditions $W_0 = 100$ g / l, $B_0 = 0.1$ g / l, we obtain the *P, S, B* dynamic pattern which are written as the following curves (Figure 2). In this point, at the grid step of τ =0,01 and N = 50,000, gives a result corresponding to 500 days.

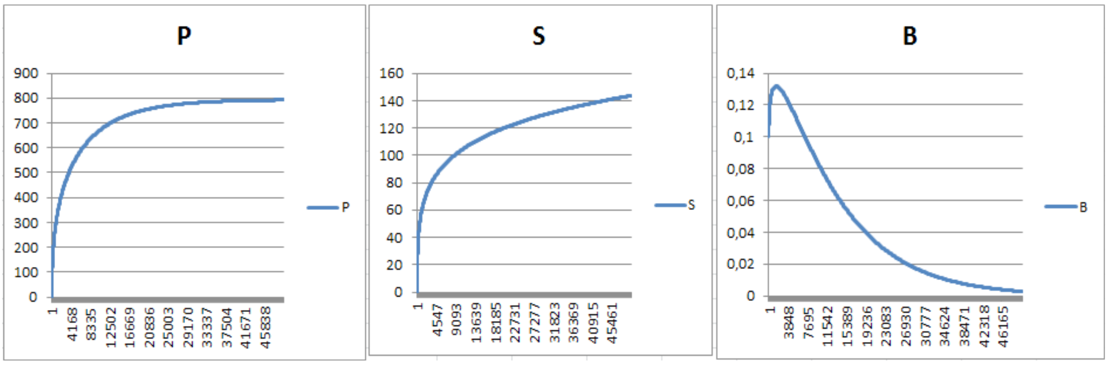

Figure 3. Change P - total biogas yield (g/l), S - concentration of hydrolysis products (g/l)
B - concentration of methanogenic microorganisms.

Set the value γ = 0.32, and Y = 0.85, and obtain the values of the total biogas yield, the hydrolysis product concentration, and the methane microorganisms biomass concentration in 500 days.

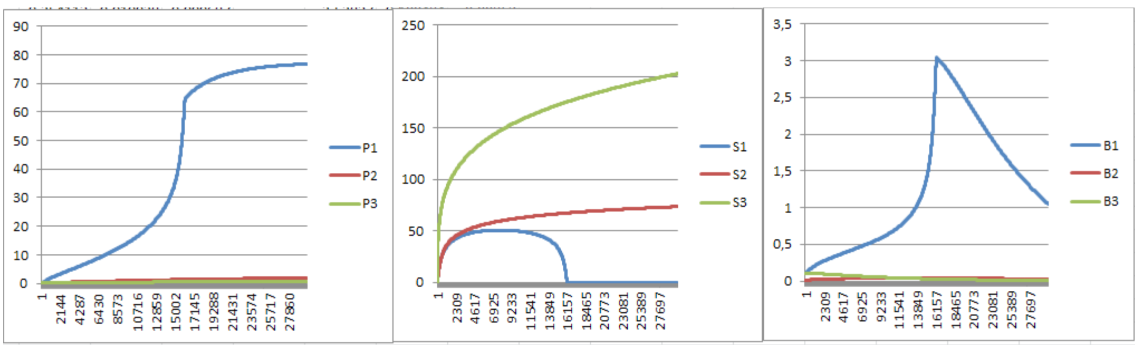

Figure 4. Changes in the yield of methane (P), the concentration of hydrolysis products (S)
and (B)-the concentration of methanogenic bacteria.

The blue lines in the figure show the curves corresponding to the W_0 = 300g / l, B_0 = 0.3 g / l initial values. Under these conditions, the reactor is operating normally.

If too few methane microorganisms are introduced (red line, W_0 = 300g / l, B_0 = 0.005 g / l, the cork effect is observed in this case. If too much organic raw material is introduced, W_0 = 1000 g / l, B_0 = 0.2 g / l, then the curve will be such as shown by the green line

Production of ethanol and its concentration. During a qualitative experiment with natural and combined samples after preliminary hydrothermal treatment, fermentation and ethanol fermentation, liquids with different volumes were obtained.

Table 2. Results of ethanol fermentation

Sample name and weight (g)	Amount of liquid after ethanol fermentation (ml)
Natural sample from the solid waste landfill of Almaty (1600 g.)	145 ml
Combined fraction (cellulose - 850g. carbohydrates-900g., lipids-500g.)	162 ml

The obtained samples with liquids were analyzed by gas chromatography with mass spectrometric detection (Agilen 7890A\5975C) to determine the chemical composition. Passing through the chromatograph, the samples are divided into components, and the mass spectrometer is responsible for their identification and analysis. This type of detection has high accuracy, its essence is reduced to recording readings not for the entire volume of the incoming ion current, but for the maximum ions for the intended molecules, and a graph of the dependence of the signal on time is built. A chromatogram is a graphical representation of the detector signal used to measure the concentration of substances in the eluate, from the time of the mobile phase. Schematically, chromatograms represent a sequence of Gaussian peaks on the baseline.

The areas of chromatographic peaks (peaks) are proportional to the volume percentages of the substance in the liquid sample, provided that the catarometer is used to analyze liquid mixtures of substances similar in their chemical structure. Usually, the area of the chromatographic peak is proportional to the concentration (C) of the corresponding component. The area of the chromatographic peak in this case is proportional to the amount of substance entering the detector at the outlet of the column. The peak area of the chromatogram is the basis for quantitative calculations of component concentrations. The sum of the peak areas is taken as 100%, and the content of the individual component is calculated in relation to the peak areas of the component to the total peak area, thus the percentage (C1, %) of each component in the sample is obtained. The concentration of each peak (%) is calculated by the peak area. Each peak corresponds to the component and the time at which it was registered, as shown in the table and on the chromatogram, also the peak areas allow you to determine the percentage of each chemical element, this analysis on the chromatograph shows that the experiment really allows you to obtain ethanol and other alcohol-containing substances.

The analysis of the model combined sample revealed the presence of ethanol in the composition, as well as alcohol-containing substances such as 1-butanol, 3-methyl, etc. Table 2 presents data on retention time, peak areas and components, intensity and concentrations of these substances.

Table 3. Component composition of the combined sample

Peak #	Ret Time (min)	Area (S)	Component	C, %	C1, %
1	1,681	4237936015	Ethanol	94	95
2	3,978	151571481	1-Butanol, 3-methyl-	62	4,2
3	6,389	3217162	Propanoic acid, 2-methyl-	73	0,1
4	9,499	28243644	Oxime-, methoxy-phenyl-_	77	0,6
5	17,185	2258941	L-α-Terpineol	71	0,1

In accordance with Table 2, a graph of gas chromatography with mass spectrometric detection is presented, where the result of recording the dependence of the intensity at the outlet of the column on time is presented. By the peak area, the concentration of each peak is calculated as a percentage.

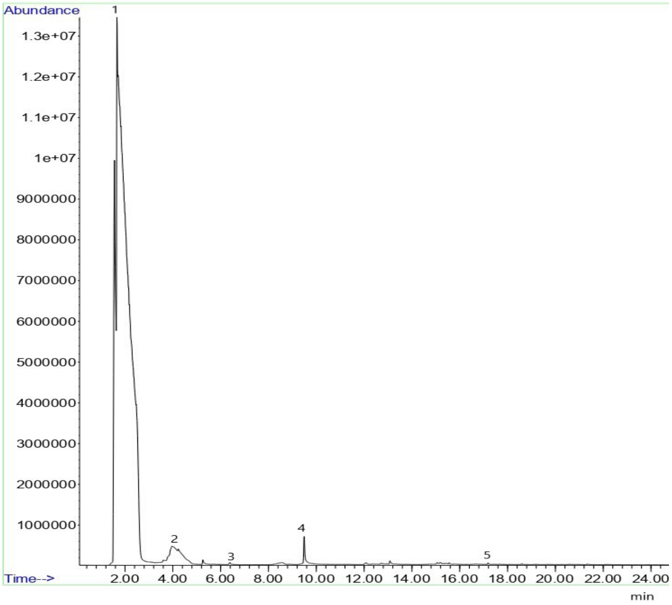

Figure 5. Chromatogram of the dependence of the concentration of the components of the combined sample (abundance) on time (time)

A natural sample from the Almaty landfill after a qualitative experiment with fermentation showed a high ethanol content of 98%. Table 4 shows the time of peak registration, the area and intensity of each component, as well as the concentrations of these substances.

Table 4. Concentration of components of a natural sample from the landfill of JSC «Tartyp» Almaty:

Peak #	Ret Time (min)	Area (S)	Component	C, %	C1, %
1	1,731	2339904556	Ethanol	91	98
2	9,559	44417720	Oxime-, methoxy-phenyl-_	80	2,4
3	14,317	5705926	Ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl carbonate	86	0,24
4	15,18	7123396	Pyrazine, tetramethyl-	81	0,30
5	16,779	2328081	2H-Pyran-3-ol, 6-ethenyltetrahydro-2,2,6-trimethyl-	63	0,10
6	17,185	1557327	α-Terpineol	67	0,06

The chromatogram of the intensity of substances, the peak area and the retention time of the sample with the organic fraction of solid household waste from the Almaty landfill is shown in Figure 6.

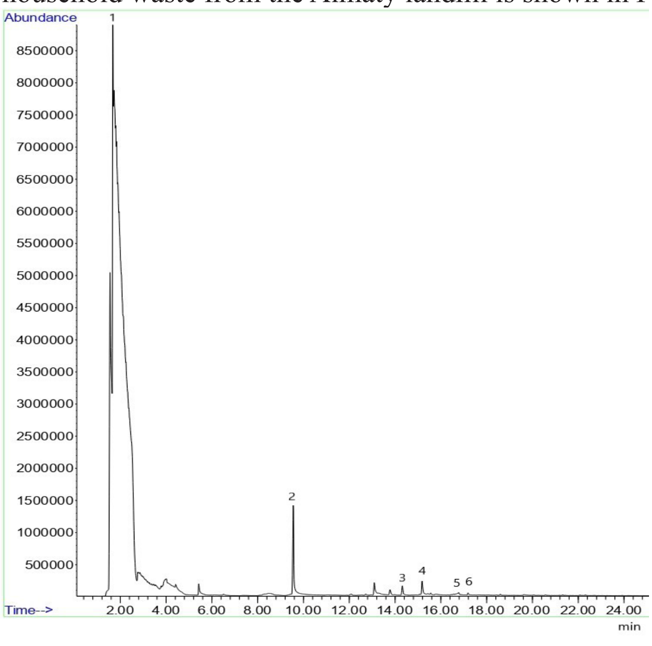

Figure 6. Graph of the concentration of components of a natural sample from the landfill of JSC «Tartyp» Almaty.

When working with waste, heat treatment is a very necessary step, since the raw materials are decontaminated, which contributes to an environmentally friendly approach. The treatment takes place at a temperature of 120 °C. Enzymatic hydrolysis of samples is carried out for deep destruction with the formation of soluble sugars under the action of poly-enzyme systems. Amylosubtilin, glucavamorin and cellulose were used as such systems.

According to the results of the experiment, two samples that were used in the experiments have a high percentage of ethanol, which indicates that the combined model composition of the sample is close to the composition of the waste of the natural sample. These close concentrations show that the organic fraction of waste is a suitable raw material for the production of ethanol or biogas. With a large discrepancy in the results of the ethanol concentration, it could be assumed that the stages of the experiment need to be changed, but since the results of the experiments have a slight difference, this implies that the conditions and temperatures are optimal and with such a technique it is possible to work on larger volumes of waste. The combined sample confirmed that in ordinary waste there is approximately the same morphological and chemical composition, which can be used by hydration and fermentation methods to produce alcohol.

Conclusion. Thus, the developed software product in the algorithmic language C++ and a simulation model using Any Logic created on the basis of a mathematical model in the form of a system of ordinary differential equations allow numerous computational experiments to simulate various scenarios of processes in biogas plants. The software products developed by the authors of the article are tested on previously known test examples. The correspondences of the step of dimensionless time to real time are established and computational experiments are carried out to identify other coefficients of the equations. The created complex of application programs allows for preliminary and predictive computer modeling of the process of obtaining biogas from various morphological composition of organic waste.

Also, ethyl alcohol is present in larger quantities in the two analyzed samples, butanol is also present in the composition, which indicates that pretreatment, fermentation and ethanol fermentation had a positive effect on the production of bioethanol. The concentration of ethanol in the natural sample from the landfill has a high index of 98%, which indicates that the natural sample of solid household waste from the landfill in Almaty has a great potential for producing alcohol. The results show that the combination of components and heterogeneous composition, as in a natural waste sample, can contribute to an increase in the concentration of alcohol and its other isomers. Probably, the mixed raw materials have more components in their composition and the effect of enzymes improves their bioavailability and prepares them for ethanol fermentation, and pretreatment promotes the breakdown of lignin and lignin cellulose, which are present in many components of solid household waste. It was experimentally proved that a natural waste sample is the best raw material for conversion into ethanol, to support the result, a model sample with an approximate composition of waste was formed, which in turn also showed a high concentration of ethanol. The high concentration of ethanol in the obtained components may indicate competitiveness with other liquid fuels, the country's energy reserves require the search for an alternative, therefore ethanol or, in other words, industrial alcohol obtained from waste can serve as fuel for cars that collect waste. JSC «Тартур» has 200 units of specialized equipment stationed at seven production bases in six districts of the city.

The results of the presented experimental work have shown that waste collected in mixed form has the potential to be used without the need for separation by fractions to produce ethanol. Consequently, the mixed raw materials contain more components, and the induction of enzymes improves their bioavailability and prepares them for fermentation with alcoholic yeast, and pretreatment promotes the decomposition of lignin and lignin cellulose, which are present in various components of solid household waste.

The experiment was conducted in a laboratory with small sample masses, on an industrial scale, after obtaining ethanol, a large amount of solid waste residues will remain, which can be affected by anaerobic digestion to produce methane, to predict the volume of biogas, a simulation model can be used. Consequently, high-concentration ethyl alcohol can be obtained from organic components of solid household waste, as well as biogas (methane) from solid residues. In addition to the direct economic effect, the production of biogas and bioethanol from waste allows:

- the optimal solution to reduce the volume of landfills;
- reduction of greenhouse gas emissions, etc.;
- reduction of natural gas consumption;
- development of alternative energy.

Supporting global efforts to reduce greenhouse gas emissions and improve the climate, these methods will effectively develop alternative energy, combining mathematical and chemical methods, by producing ethanol and predicting the production of methane from the organic fraction of solid household waste.

Темирбекова М.Н.[1*], Темирбеков Н.М.[2], Вуйцик В.[3], Алиярова М.Б.[1], Елеманова А.А.[1]

[1]Алматы энергетика және байланыс университеті. Ғ. Дәукеева, Алматы, Қазақстан;
[2]Қазақстан Республикасының Ұлттық инженерлік академиясы, Алматы, Қазақстан;
[3]Электроника және ақпараттық технологиялар департаменті, Люблин технологиялық университеті, Польша.
E-mail: *m.temirbekova@aues.kz*

ИМИТАЦИЯЛЫҚ МОДЕЛ АРҚЫЛЫ ЭТАНОЛ ЖӘНЕ БИОГАЗ АЛУ ҮШІН ҚАТТЫ ҚАЛДЫҚТАРДЫҢ ОРГАНИКАЛЫҚ ФРАКЦИЯСЫН ПАЙДАЛАНУ

Аннотация. Бұл жұмыста биогаз қондырғысының жаңғыртылған конструкциясын пайдалана отырып, қатты тұрмыстық қалдықтар полигонында биогазды жинау және кәдеге жарату тиімділігі қарастырылады. Қатты қалдықтармен тиімді жұмыс істеу халықтың денсаулығы мен қоршаған ортаны қорғауды қамтамасыз ету үшін, өңдеудің әртүрлі тәсілдерін, технологиялары мен тұжырымдамаларын қолдануды көздейді.

Биогаз қондырғысында болатын үдерістердің оңтайлы режимі компьютерлік модельдеумен анықталады. Биогаз қондырғысында болатын биохимиялық процестерді сипаттау үшін математикалық модельдің параметрлерін анықтау жүргізілді. Математикалық модельді шешу үшін екі тәсіл қолданылады: дифференциалдық теңдеулер жүйесін шешудің айырмашылық әдісі және кез-келген логикалық пакетті қолдана отырып модельдеу. С++ алгоритм тілінде компьютерлік бағдарлама құрастырылды. Нәтижелері график түрінде келтіріліп, олардың сапалы көрінісі болып жатқан процестерге сәйкес келетін көптеген есептеулер жүргізілді. Жасалған компьютерлік бағдарлама субстраттың көлеміне, метаногенді микроорганизмдерге және температура режиміне байланысты биореакторда болатын анаэробты ашытудың алдын-ала болжамын жасауға мүмкіндік береді. Қатты тұрмыстық қалдықтарды алдын-ала өңдеу, ашыту, этанол ашыту және анаэробты ашыту сияқты балама әдістерге көп көңіл бөлінеді. Осы әдістердің көмегімен полигоннан қатты тұрмыстық қалдықтардың 1,6 кг органикалық фракциясынан құрамында спирт бар заттар бар сұйықтық алынды, онда этил спиртінің пайыздық құрамы 98% - ды құрады, сондай-ақ қалдықтардың модельдік фракциясының 2,3 кг-нан этанол (95%) алынды. Сондықтан қатты тұрмыстық қалдықтар ластану көзі емес, өміршең энергия көзі бола алады. Осылайша, мақалада биогазды математикалық модельдеуді қолдану мүмкіндігі, сондай-ақ органикалық фракцияның қалдықтарынан сапалы эксперимент және оларды одан әрі этанолға айналдыру мүмкіндігі қарастырылады.

Түйінді сөздер: имитациялық модельдеу, биогаз, этанол, математикалық модельдеу, тұрмыстық қатты қалдықтардың органикалық фракциясы, термиялық өңдеу, ашыту, этанол ашыту.

Темирбекова М.Н.[1*], Темирбеков Н.М.[2], Вуйцик В.[3], Алиярова М.Б.[1], Елеманова А.А.[1]

[1]Алматинский университет энергетики и телекоммуникаций им. Г. Даукеева, Алматы, Казахстан;
[2]Национальная инженерная академия Республики Казахстан, Алматы, Казахстан;
[3]Департамент электроники и информационных технологий, Люблинский технологический университет, Польша.
E-mail: *m.temirbekova@aues.kz*

ИСПОЛЬЗОВАНИЕ ОРГАНИЧЕСКОЙ ФРАКЦИИ ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ ДЛЯ ГЕНЕРАЦИИ ЭТАНОЛА И БИОГАЗА С ИСПОЛЬЗОВАНИЕМ ИМИТАЦИОННОЙ МОДЕЛИ

Аннотация. В этой работе обосновывается эффективность сбора и утилизации биогаза на полигоне твердых бытовых отходов с использованием биогазовой установки модернизированной конструкции. Эффективное обращение с твердыми отходами предполагает применение различных подходов, технологий и концепций обработки для обеспечения охраны здоровья населения и окружающей среды. Оптимальный режим процессов происходящих в биогазовой установке определяется компьютерным моделированием. Проведена идентификация параметров математической модели для описания биохимических процессов, происходящих в биогазовой установке. Для решения математической модели используется два подхода: конечно-разностный метод решения системы дифференциальных уравнений и имитационное моделирование с помощью пакета Any Logic. Составлена компьютерная программа на алгоритмическом языке С++. Проведены многочисленные расчеты результаты которых приведены в виде графиков и их качественная картина согласуется с происходящими процессами. Созданная компьютерная программа позволяет сделать предварительный прогноз анаэробного брожения происходящих в биореакторе в зависимости от объема субстрата, метаногенных микроорганизмов и температурного режима. Повышенное внимание привлекают альтернативные методы как предварительная обработка твердых бытовых отходов, ферментация, этанольная ферментация и анаэробное сбраживание. С помощью данных методов из 1,6 кг органической фракции твердых бытовых отходов из полигона получена жидкость со спиртосодержащими веществами, в которой процентное содержание этилового спирта составило 98%, также из 2,3 кг модельной фракции отходов был получен этанол (95%). Следовательно, твердые бытовые отходы могут быть жизнеспособным источником энергии, а не источником загрязнения. Таким образом, в статье рассматривается возможность использования математического имитационного моделирования биогаза, а также качественный эксперимент из остатков органической фракции и дальнейшее их преобразование в этанол.

Ключевые слова: имитационное моделирование, биогаз, этанол, математическое моделирование, органическая фракция твердых бытовые отходов, термальная обработка, ферментация, этанольное брожение.

Information about authors:

Temirbekova M.N. – PhD student, Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev, Almaty, Kazakhstan; E-mail: *m.temirbekova@aues.kz*; https://orcid.org/0000-0003-1911-289X;

Temirbekov N.M. – Doctor of Physical and Mathematical Sciences, Professor, Vice-President of the National Engineering Academy of the Republic of Kazakhstan; Almaty, Republic of Kazakhstan; E-mail: temirbekov@rambler.ru; *https://orcid.org/0000-0001-7542-3778*;

Wojcik W. – Professor of Technical Sciences; Director (Institute of Electronics and Information Technology), Lublin University of Technology, Nadbystrzycka 38a, 20-618 Lublin, Poland; E-mail: *waldemar.wojcik@pollub.pl*; https://orcid.org/0000-0002-0843-8053;

Aliyarova M.B. – Cand.Sc. (Tech.), Almaty University of Power Engineering and Telecommunications named after G. Daukeev, Almaty, Kazakhstan, E-mail: *m.aliyarova@aues.kz*; *https://orcid.org/0000-0003-1834-4509;*

Elemanova A.A. – PhD student, Almaty University of Power Engineering and Telecommunications named after G. Daukeev, Almaty, Kazakhstan, E-mail: *a.elemanova@aues.kz*.

REFERENCES

[1] Kim S., Dale B.E., 2004. Global potential bioethanol production from wasted crops and crop residues. Biomass Bioenergy 26 (4), pp.361–375. (in Eng.).

[2] Reijnders L., 2008. Ethanol production from crop residues and soil organic carbon. Resource. Conserv. Recycl. 52(4), pp.653–658. (in Eng.).

[3] Sarkar N., Ghosh S.K., Bannerjee S., Aikat K., 2012. Bioethanol production from agricultural wastes: an overview. Renewable Energy 37 (1), pp. 19–27. (in Eng.).

[4] Ma Y., Cai W., Liu Y., 2017a. An integrated engineering system for maximizing bioenergy production from food waste. Appl. Energy 206 (C), pp. 83–89. (in Eng.).

[5] Yan S., Li J., Chen X., Wu J., Wang P., Ye J., Yao J., 2011. Enzymatical hydrolysis of food waste and ethanol production from the hydrolysate. Renewable Energy 36 (4). (in Eng.).

[6] Nozhevnikova A.N. Biotechnology, Microbiology of anaerobic processing of organic municipal waste. 2016, P. 320 (in Russ)..

[7] Alavi Moghadam M.R., Mokhtarani N., Mokhtarani B., 2009. Municipal solid waste management in Rasht City, Iran. Waste Manage. 29 (1), pp. 485–489 (in Eng.).

[8] Sharholy M., Ahmad K., Vaishya R., Gupta R., 2007. Municipal solid waste characteristics and management in Allahabad, India. Waste Manage. 27 (4), pp. 490–496 (in Eng.).

[9] Talyan V., Dahiya R., Sreekrishnan T., 2008. State of municipal solid waste management in Delhi, the capital of India. Waste Manage. 28 (7), pp. 1276 –1287 (in Eng.).

[10] Yousuf T.B., Rahman M., 2007. Monitoring quantity and characteristics of municipal solid waste in Dhaka City. Environ. Monit. Assess. 135 (1), pp. 3–11 (in Eng.).

[11] Taherzadeh M.J., Karimi K., 2008. Pretreatment of lignocellulosic wastes to improve ethanol and biogas production: a review. Int. J. Mol. Sci. 9. (in Eng.).

12] Keshuov S.A., Barkov V.I., Tokmoldaev A.B. «Application of biogas plants in animal husbandry» Almaty, 2012. (In Russ.).

[13] Zhapparova Zh.M., EcoInform, Materials of the 5th International Conference "Cooperation for Solving the Waste Challenge", 195–197, (2008) (In Russ.).

[14] Ruzhinskaya L.I., Fomenkova A.A. «Mathematical modeling of processes of anaerobic shedding of organic substrate. Review.» Scientific Journal «Sciencerise» No.4/2(4)2014. pp. 63-69. (in Russ.).

[15] Lo H.M., Kurniawan T.A., Sillanpää M.E.T., Pai T.Y., Chiang C.F., Chao K.P., Liu M.H., Chuang S.H., Banks C.J., Wang S.C., Lin K.C., Lin C.Y., Liu W.F., Cheng P.H., Chen C.K., Chiu H.Y., Wu H.Y. «Modeling biogas production from organic fraction of MSW co-digested with MSWI ashes in anaerobic bioreactors» Bioresource Technology Volume 101, Issue 16, 2010. pp. 6329-6335 (in Eng.).

[16] Mandy Gerber, Roland Span «An Analysis of Available Mathematical Models for Anaerobic Digestion of Organic Substances for Production of Biogas» IGRC 2008 (in Eng.).

[17] Topazh A.G., Vigont V.A., Khvorova L.A. «Simulation model of the biogas production process from multicomponent plant raw materials - analysis and parametric optimization» Chemistry of plant raw materials. - 2018 №1. pp.171-184 (in Russ.).

CONTENTS

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www:nauka-nanrk.kz

http://www.geolog-technical.kz/index.php/en/

ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 14.02.2022.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
11,5 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19