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Ecology

Study of some Technological and Economical Characteristics of Processing of the Solid Municipal Waste to Methanol

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ABSTRACT. Industrial processing of the solid municipal waste (MSW) into valuable marketable products is an economically prospective and environment friendly method for sharp reducing of the total amount of generated and disposed waste. One of the most promising ways is the processing of organic component of municipal waste into methanol. The main factors affecting the environmental, economic and social effectiveness of the industrial treatment are the composition of utilized waste mass and catalytic activity of the used compounds. The novelty of the present research is the complex utilization of the mixture of dried brown coal slurry and organic component of the MSW, and the experimental study of metallic, carbonate and hydroxide catalysts with aim to find the optimal conjunction of the catalysts and investigate the possibility of the synergetic action of mixtures of catalysts for gasification of the tested mixtures, followed by methanol synthesis using the pilot plant KPUOP-1. The capacity of electric power generation was tested and assessed using the commercially available gas generator AKSA AMG1500. The obtained data showed that the use of tested mixtures of the brown coal and organic component of the previously separated SW increased the capacity of gas and methanol production for 20-25 %. Combination of calcium hydroxide with sodium and potassium carbonates (30%/49%/21%) was significantly more effective in comparison with the combination of sodium and potassium carbonates (70%/30%) or compared to Raney nickel catalyst. Additional research for find and assess the optimal synergetic combinations is needed. © *2019 Bull. Georg. Natl. Acad. Sci.*

Key words: municipal solid waste, gasification, methanol, economic, environment, methanol, catalysts

Especially active scientific research on new waste management practices in EU [1] and Georgia [2] has begun after the Chairman of the European Commission confirmed the rapid movement of the European Union towards a full scale development and implementation of the "circular" economy principles. The environmental situation in Georgia can be characterized as an urgent object for a complex scientific and practical research. Our analysis showed that responding of Georgia's most severe environmental problems is linked with the following issues: The need for farther improvement

of the legislative basis is accurately and consistently indicated in the National Strategy of Waste Management (2016-2030) and the National Action Plan (2016-2020); the increased morbidity of population and environment pollution in Georgia is directly correlated with the shortages in waste management [3-6]; the territories polluted by oil and oil products in Georgia cover hundreds of hectares of vulnerable (sensitive) areas and are characterized by high risks for ecosystems; the Solid Waste Management State Company actively works to improve the management of municipal solid waste in Georgia, but without implementation of the environment friendly and profitable modern technologies it will be impossible to solve the problem; hundreds of thousands of tons of agricultural residues are generated that remain unused and pose considerable environmental hazards.

One of the most prospective methods to combat the MSW management problem in Georgia can be the industrial processing of waste into marketable products, namely syngas and methanol (e. g., [7-9]). Important factors influencing the capacity, energy efficiency, socio-economic and environmental impact of processing are the waste composition and effectiveness of catalysts. Most of previous studies in this field were focused on the utilization of solely organic component of the MW after recycling (removal of metal scrap, glass, cardboard, valuable plastic) using metallic (Pt, Ni-Al), carbonate, nitrate or hydroxide (calcium hydroxide, aluminum catalysts (e. g. [10]). The main novelty of our research was the gasification of the mixture of waste coal slurry generated at Tkibuli coal mine and the organic component of MSW (e. g., generated at the Batumi, Tsageri, Kutaisi, Rustavi and Tbilisi regional landfills), followed by methanol synthesis and electric power generation using the appropriate gas generator AKSA AMG1500. Our research was executed using a transportable small scale plant for waste gasification and methanol synthesis KPUOP-1 and involved systematization of literary data, additional sampling and analysis of MSW, experimental testing of capacity of processing of the waste into methanol, analysis of the obtained product and estimation of the possible environmental and economic efficiency of industrial processing cycle.

The average composition of the utilized waste samples mixed with coal slurry is given in Table 1.

The main characteristics of methanol processed using alkaline earth and alkali metal catalysts mixture, alkali metal catalysts mixture and Raney nickel catalyst are presented in Table 2.

Table 1. The average composition of the utilized waste samples mixed with coal slurry

Dried brown coal dust (mas %)	Food waste residues (mass %)	Agricultural residues (mass %)	Non-recyclable waste (mass %)	Water/other impurities
30	25	35	2-3	The rest
20	30	35	3-4	The rest
50	15	25	2-3	The rest

Table 2. Experimental data on chemical composition of methanol processed from the gasification products

Type of catalyst	Density, g/cm^3	Boiling Interval, ^{0}C	Water, mass %	Iron, mass %	Aldehydes and ketones, mass %	Chlorine, mass %
$Ca(OH)_2$-Na_2CO_3-K_2CO_3	0.791	64.0±0.5	≤0.05	≤0.00001	≤0.03	≤0.0001
Na_2CO_3-K_2CO_3	0.791	64.5±0.5	≤0.07	≤0.00003	≤0.05	≤0.001
Ni-Al	0.792	65.0±0.5	≤0.08	≤0.0005	≤0.08	≤0.001

All obtained samples correspond to standard requirements for the technical methanol grade 1 (in case of Ca $(OH)_2$-Na_2CO_3-K_2CO_3 catalyst) and grade 2 (in case of $Ca(OH)_2$-Na_2CO_3-K_2CO_3 and Ni-Al catalyst).

The main averaged experimental and calculation data on the capacity of producing methanol, methane and generating electricity using the model plant KPUOP-1 are given in Table 3.

Table 3. Experimental and assessment data on the daily and annual capacities

Number of samples	Type of catalyst	Capacity, t/hour (methanol)	Annual capacity, t/year (methanol)	Capacity, m^3/hour (methane)	Annual capacity, 1000 m3/ year (methane)	Electricity generation annual capacity, Average megawatt
24	Raney nickel	1.5	12 500	2500	18 500	20000
24	Na_2CO_3-K_2CO_3	1.6	13 300	2650	13 700	21500
24	$Ca(OH)_2$-Na_2CO_3-K_2CO_3	1.8	15 000	3000	22 000	24000

The Na_2CO_3-K_2CO_3 mixture was formed by uniform mixing of 70% (molecular mass) of sodium carbonate and 30% (molecular mass) of potassium carbonate. The Ca $(OH)_2$-Na_2CO_3-K_2CO_3 mixture was formed by uniform mixing of 30% of $Ca(OH)_2$, 49% of Na_2CO_3 and 21% of K_2CO_3.

The following conclusions are made: 1. The existing amount of the solid municipal waste disposed in Georgia on the authorized landfills is about 840-850 thousands of tons (including about 60% or 500 thousands of tons of organic compounds) and is growing for 2-3% annually. About 10-12% of the generated solid municipal waste is disposed on the unauthorized landfills, which pose the main threats for the health of population. 2. Processing of about 500 thousands of tons of organic compounds into about 120-150 thousands of tons of methanol is possible by means of about 100 small- and medium-scale plants located near the newly constructed sanitary landfills. The total investments and the return period are estimated as USD 80 million and 5-6 years respectively. 3. New technologies developed in Georgia can be effectively used to process the organic component of municipal and industrial wastes into methane, gaseous and liquid fuels, charcoal, industrial quality electricity, etc.

ეკოლოგია

მყარი საყოფაცხოვრებო ნარჩენების მეთანოლად გადამუშავების ტექნოლოგიური და ეკონომიკური მახასიათებლების კვლევა

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მყარი საყოფაცხოვრებო ნარჩენების (მსნ) გადამუშავება ბაზარზე მოთხოვნად პროდუქტებად, წარმოადგენს ეკონომიკური და გარემოსდაცვითი თვალსაზრისით, პერსპექტიულ მეთოდს გენერირებული და განთავსებული ნარჩენების საერთო რაოდენობის შესამცირებლად. ერთ-ერთ ყველაზე უფრო ქმედით საშუალებას წარმოადგენს მსნ ორგანული კომპონენტის გაზიფიკაცია და მეთანოლად გადამუშავება. სამრეწველო გადამუშავების გარემოსდაცვითი და სოციალურ-ეკონომიკური მახასიათებლების განმსაზღვრელ მნიშვნელოვან ფაქტორებს წარმოადგენს გადასამუშავებელი მსნ შემადგენლობა და გამოყენებული ნაერთების კათალიტური აქტივობა. წარმოდგენილი კვლევის ძირითადი სიახლეა მურა ნახშირის გამომშრალი შლამის და მსნ ორგანული კომპონენტის ნარევის კომპლექსური უტილიზაციის კვლევა, ლითონური (Ni-Al), კარბონატული (ნატრიუმის და კალიუმის კარბონატები) და ჰიდროქსიდური (კალციუმის ჰიდროქსიდი) კატალიზატორების ექსპერიმენტული შესწავლა, მათი ერთობლივი გამოყენების ოპტიმალური მეთოდიკის შესამუშავებლად და **KPUOP-1** საპილოტე დანადგარის გამოყენებით მეთანოლის შემდგომი სინთეზისთვის სატესტე ნარევების გაზიფიკაციის პროცესში კატალიზატორების სინერგიული მოქმედების შესაძლებლობის შესაფასებლად. კომერციულად მისაწვდომი გაზ-გენერატორის **AKSA AMG1500** გამოყენებით ჩატარდა ელექტრული სიმძლავრის გენერაციის ტესტირება და პროცესის წარმადობის შეფასება. ტესტირების და შეფასების შედეგებმა გვიჩვენა, რომ გამოკვლეული შემადგენლობის წინასწარ სეპარირებული მსნ და მურა ნახშირის შლამის ნარევების გამოყენებამ შეიძლება გაზარდოს გაზიფიკაციის და მეთანოლის მიღების პროცესების წარმადობა 20-25%-ით. კალციუმის ჰიდროქსიდის ნატრიუმის და კალიუმის კარბონატებთან ნარევი (30%/49%/21%) მნიშვნელოვნად უფრო ეფექტური აღმოჩნდა ნატრიუმის და კალიუმის კარბონატების ნარევთან (70%/30%) ან რენეის ნიკელის კატალიზატორთან შედარებით. საჭიროა დამატებითი კვლევის ჩატარება კატალიზატორების ოპტიმალური სინერგეტიკული შემადგენლობების დასადგენად.

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