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Recycling of technogenic resources by microbial bio-conversion

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Abstract
In the article, the author standpoint concerning recycling of coal production waste into biogas is stated. The innovative theoretical and practical results of researches showing the possibility of global introduction of emerging technologies of energy resources obtaining with the use of biocenosis are presented.
Key words: RECYCLING, TECHNOGENIC RESOURCES, COAL WASTE, BIOTECHNOLOGY, BIOTRANSFORMATION, BIOCENOSIS

Scales expansion of anthropogenic activities, continuous growth of natural resources consumption including metals lead to increase in load on environment; this stipulates the necessity of solution of one of the most actual problems of our age, namely, ensuring of rational use of natural resources and environment protection.

Widespread use of different types of coal is related to the need of storage and processing of carbonaceous waste. It requires considerable expenses and leads to long-term negative impact on mining regions ecology. The use of biotechnological processes is one of the promising directions.

Speaking about increasing biotechnological potential capacity of microorganisms consortium in various branches of economy, the prominent scientist G. A. Zavarzin noted: "The most conservative estimates lead to conclusion that the producing operations based on application of microbial community exceed producing operations based on pure cultures in the economic importance by dozens times. At the same time, "costs for basic researches of pure cultures exceed costs for studying of industrial application of microbial communities by dozens and hundreds times" [1].

Authors of article studied and published the results of researches on possibility of microorganisms use for coal waste recycling [2]. The researches focused on formation of microorganisms consortium for biotransformation of coal waste in the base products (biogas and organomineral fertilizers) are presented in this work.

Naturally, the process of natural biocenosis formation in combination with coal upgrading takes place. The coal is upgraded by decrease in the hydrogen content due to methane release and by reduction of oxygen quantity when releasing of carbon dioxide. In the course of coal mining, when the native state of layers is violated by the human operating activities, other forms of microbial flora are developed spontaneously on coal surface; these developments lead to some chemical and structural transformation [3, 4].

Intensifying of such processes for the purpose of coal biotransformation is possible via development of microbial flora forms, which are active in relation to coal. Anaerobic methanogenic consortium of the mixed microorganisms is the most acceptable for destruction of coal organic substance.

In course of studying of bio-conversion process, the selection of the working biocenoses was made and proved. They are mixed anaerobic methanogenic associations, which carry out biotransformation of carbonaceous substance of coal waste into biogas the most effectively. The following cultures are of such kind: Clostridium themocellum + Methanobacterium thermoformiclum; Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica, and also anaerobic consortium of methane digester for waste water purification.

When recycling of anthracite by use of cultures Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica and anaerobic consortium of methane digester, the maximum concentration of methane reached 25%. During methanogenesis of brown coal by thermophilic couple Clostridium themocellum + Methanobacterium thermoformiclum and anaerobic community of methane digester, the concentration of methane reached 40%.

Preliminary aerobic transformation of coal by fungus culture Asp.niger with further methanation by cultures group Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica allowed increasing of methane output up to 65% in case of bio-conversion of brown coal and up to 30% in case of anthracite recycling; thus, methane productivity was 0.337 m^3/t per day; anthracite productivity was 0.586 m^3/t per day. The coal waste organic component conversion degree determined by change of percentage of ash before processing and after bacterial influence represents various values for each group of cultures and varies in the following range: 3.27-10.22% (in case of anthracite bioutilization) and 4.89-12.2% (in case of brown coal) [5].

It is known that anaerobic bio-conversion of complex organic substrata is divided into three stages: hydrolysis, acidogenesis and methane generation. A certain group of microorganisms is responsible for each stage. The first group includes hydrolytic bacteria, which provide initial hydrolysis of complex substrata to low-molecular organic compounds. The second group is presented by the acidogenic bacteria producing acetic acid and hydrogen. This group includes genus representatives Clostridium, Pseudomonas, Baccilus [6,7].

Actually, the stage of methane generation is carried out by family Methanobacteriaceae. Depending on the consumed substratum, this group is subdivided into chemolithotrophs (bacteria consuming hydrogen and carbon dioxide) and the acetotrophs (bacteria consuming mainly acetic acid). The stage of a methanogenesis is limitative. In case insufficient activity of methanogens- chemolithotrophs and excess amount of organic substratum, the number of hydrogen ions inhibiting the acidogenes activity increases.

Reasonability of division of process stages for

members of microorganisms anaerobic community was confirmed during experiments on purposely designed installation [4]. The stages were divided basically due to the use of two various reservoirs connected to gas-meters. The liquid moved from one vessel filled with nutrient medium containing the culture of microorganisms into another vessel. The anthracite returned to the first vessel again after filtration through previously processed by 5% solution NaOH. The size of anthracite grains is 1mm; process temperature is 50 C^0. Concentration of methane on the 14th day reached 35.25%, cultivation was being conducted for 20 days.

Studying of chemical reagents impact on coal substratum [8], namely further transformation by anaerobic community, produced positive results in case of processing by solutions of 1% NaOH, 5% NaOH and temperature hydrolysis in 1% solution of KOH. The best results were achieved when pre-processing was conducted by 5% NaOH solution. Results of researches are presented in the Table.

Table 1. Results of microbial transformation of coal (anthracite)

Substrate	Final value pH	Concentration of methane	Volume of methane, cm^3
Coal + 1% HNO_3	7.2	3.28	0.098
Coal + 5% HNO_3	7.15	2.21	0.06
Coal + 1% NaOH	7.7	3.93	0.09
Coal + 5% NaOH	7.92	35.25	3.525
Coal + 1% KOH	7,6	2.5	0.095
Coal + 5%	7.63	2.13	0.074
Coal + 20 ml of nutrient medium	-	0.81	0.029
Anthracite without processing	7.2	3.03	0.114

However, with transition from small volumes to industrial ones, the rate and intensity of biochemical reactions can undergo considerable changes. Therefore, full-scale experiments for the purpose of technologies creation for coal waste processing were carried out. The researches were conducted with two groups of cultures Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica and methanogenic consortium of methane digester.

Experiment was carried out with application of stages separation method and without it. Members of methanogenic association were subject to separate cultivation: Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica.

Full-scale researches were conducted in the 3 m^3 reactor; in case of separation of stages, the volume of the first reactor was $2m^3$, the second was $3m^3$. In the first case, 675 kg of anthracite culm were subject to recycling; in the second case, 320 kg were recycled. The inoculum with the content of crude biomass of 0.04 g/l was used in a production cycle of industrial biorefinery. The initial water coal mix is formed of the following components: solid phase (coal of certain fraction) - up to 40%, liquid phase - up to 60%, inoculum of the adapted microorganisms in the form of water coal suspension - up to 30%, the rest is water and the corrective additives of mineral compounds.

When separating of process stages, the basic technological parameters are the following: S:L ratio - 1:6,5, initial concentration of microorganisms – 0.015 g/l, average concentration of methane - 20%, productivity on methane – 0.204 m^3/t per day. Without separating cultivation of acid-forming and methanogenic micro-flora, average concentration of methane was up to 12% when using of group of cultures Ps.aeruginosa + B.megaterium + M. Omelianskii + Ms. Methanica and up to 17% when biogasification was carried out by consortium of methane digester, productivity on methane was 0.138 m^3/t per day and 0.155 m^3/t per day respectively.

Thus, as a result of the conducted researches, the following theoretical development was confirmed: modeling of waste bio-conversion process with separation of stages and optimization of processing technology on the basis of selection of the most active biocenosis of microorganisms.

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