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Microbiological underground methanation: principle, bio-chemical and hydrodynamic models, and self-organization phenomena

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A new technology is proposed, which consists of injecting H2, CO2 and bacteria into aquifers or depleted gas/oil reservoirs in order to convert them into methane. The conversion occurs by means of bacteria, which use hydrogen and carbon dioxide for their respiratory metabolism. The product of this bio-chemical activity is methane. Thus, we deal with the creation of the artificial reservoirs of natural gas. This also resolves two other fundamental environmental and energy problems: (i) reducing CO2 emissions into the atmosphere by converting CO2 to methane; and store excessively generated electricity from wind and sun in the form of hydrogen (this excess electricity can be converted to hydrogen).
The coupled bio-chemical and hydrodynamic model of the system is developed. The particular attention was payed to the adequate description of the bacterial kinetics and bio-chemical reactions. The mathematical analysis of this model revealed the existence of the phenomena of self-organization caused by the Hopf-Andronov bifurcation. This leads to the appearance of space oscillatory waves of concentration having multi-scale structure. Depending on the structure of these oscillations, they may be favourable or not for the efficiency of the methane production. Thus, the criteria of the efficiency of the underground methanation are strictly related to the mathematical criteria of the existence of self-organization regimes. Such exact criteria of the appearance of the auto-waves have been obtained. They depend on the injection rate, on the composition of the injected gas, and on the bacterial kinetics. Due to the analytical and numerical simulations, we have obtained the estimations for essential parameters of this technique, as the optimal composition of the injected gas, the characteristic time of conversion, and the evolution of the composition of the resulting gas in time.

References

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