Biochemical patterns and waves in underground storage of hydrogen and CO_2

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Underground storage of H_2 and CO_2 mixtures in aquifers and their transformation into methane by bacteria can be an efficient technology for the creation of artificial reservoirs of natural gas. The interaction between biochemical reaction and species transport leads to the formation of nonuniform structures in space called autowaves (patterns and waves), which reduces the efficiency of the conversion. The objective is thus to maintain the injection regimes avoiding the formation of autowaves. The theory of autowaves is well developed for two-component systems and much less extended to three- and four-component systems, which is our case. For a given kinetics of the population growth, we have determined, through stability analysis, several types of autowaves that can occur in a storage. Among them we find the Hopf-Andronov fluctuations in time, Turing's oscillations in space, mixed spatial and temporal oscillations, standing waves and traveling waves. We extended our analysis to heterogeneous media (blocks-fractures) and detected new dynamic patterns in the form of flashes randomly traveling over the domain. For all types of the autowaves, we have detected the exact criteria of their existence. We also detected the critical modes of perturbation that provoke fluctuations. The analytical studies have been confirmed by numerical tests. We applied this theory to model the feasibility of storing hydrogen in a depleted gas reservoir. 3D simulations were performed with the open code DuMu^X. Several examples reveal the appearance of spatial autowaves in real conditions.

References

[1] M. Panfilov, *Physicochemical fluid dynamics in porous media. Applications in geosciences and petroleum engineering.* Wiley-VCH, 2019.

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