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Modelling and Simulation Experiments on Directed Movement of Bacteria in Aqueous Medium with Counter-Diffusive Substrate Uptakes

Particulate Organic Matter(POM), sediment grains, microplastics serve as substrates for various microorganisms, including planktonic bacteria, which are suspended in aqueous medium. Planktonic bacteria colonize particles' surfaces by forming a bacterial biozone and consume released nutrients to stimulate growth. For sinking particle plume in marine ecosystems, this bacterial activity and reshaping of the carbon plume affect marine carbon pump and thus carbon sequestration in deep sea. The nutrient gradient drives accumulation of bacteria as a response to directed movement. We develop a mathematical model that describes the planktonic bacterial growth and lysis, movement of cells by diffusion and a chemotaxis-like directed movement and perform simulation experiments. We assume that the biomass growth depends on the concentration of substrates, such as carbon, an electron donor, and oxygen, an electron acceptor. Carbon, sourced from a particle surface wall, diffuses into domain from one boundary, while oxygen enters from opposite boundary, a distant source, establishing a counter-diffusion system. These two growth-limiting substrates control direction of transport of cells and bacterial colony accumulates in regions with favorable growth conditions. The Keller-Segel-Patlak type one-dimensional model with two stimuli consists of three non-linear PDEs. The transport terms in bacterial concentration equation are discretized in space using a flux-conservative-finite-volume method and substrate equations are discretized using library 'ReacTran' from 'R'. Then three discretized one-dimensional equations are solved numerically using a time-adaptive method from 'R'. The energy estimate method is applied to linearised system around uniform steady state to explore the long and short time behaviour of bacterial concentration.