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SIMULATION OF A SEQUENTIAL DELIVERY MICROFLUIDIC PAPER-BASED ANALYTICAL DEVICE

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Abstract. Microfluidic paper-based analytical devices (μPADs) have gained popular interest making significant strides in the expansion of point-of-need analytical applications. This work focuses on the numerical prototyping of a two-dimensional paper network designed to sequentially deliver three fluids to a test zone. In this case, an immunological reaction–based system is considered, as far as these have demonstrated efficiency in several fields and applications. However, immunological reactions require a correct sequence for the delivering of the different reagents (sample, antibodies, reporter particles, etc.). Consequently, a precise simulation of the different delivering processes is mandatory, including the transport and reaction processes in order to complete the numerical assay. Under these requirements, the numerical model couples the Richards equation of flow through porous media to the species transport equation with high-order reaction terms. The porous medium created by the cellulose fibers is considered a network of tortuous capillaries and macroscopic parameters represent it following an effective medium approach. The model incorporates a novel exhaustible inlet boundary condition and a numerically efficient reactive scheme. Numerical prototypes were implemented in OpenFOAM®software, using the `porousMicroTransport` toolbox. The proposed numerical prototype serves as a validation of the new boundary condition as well as to corroborate that `porousMicroTransport` is a valuable tool for μPAD design. Moreover, the results can be used in the near future to build new devices that require sequential delivery operational protocols for a wider variety of analytical applications.