Artifact of “Breakthrough” osmosis or what may be wrong with local Spiegler-Kedem-Katchalsky equations with constant coefficients.

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Osmosis – solution (solvent) flow through non-perfectly (perfectly) semipermeable membranes – is a fundamental classical phenomenon of major practical importance. One of its potentially useful technological applications is the Pressure Retarded Osmosis employed for energy harvesting from salinity variations. In this process the flow resulting from the osmotic pressure drop between fresh and saline water is used to drive a turbine. Unfortunately, at the current stage, in spite of its extreme simplicity and conceptual beauty, this process does not appear to be practically viable due to insufficient power efficiency. This assessment could be radically changed by operating pressure retarded osmosis the recently theoretically predicted “Breakthrough” operation mode. In this mode, the solute concentration at the interface between the porous support and the dense selective barrier layer of a non-perfect (‘leaky’) asymmetric membrane employed in process decreases with the increase of draw concentration, and, thus, the impeding effect of internal concentration polarization is eliminated. The existence of this mode was predicted based on the analysis of the system of classical local Spiegler-Kedem-Katchalsky equations of membrane transport in the barrier layer employing three constant coefficients: solute permeability, solute reflection coefficient and hydraulic permeability. In a still more recent study the physical feasibility of “Breakthrough” mode was contested and doubt was casted upon the suitability of Spiegler-Kedem-Katchalsky equations with constant coefficients for modeling of Pressure Retarded Osmosis. We re-derive the Spiegler-Kedem-Katchalsky equations based on a simple capillary friction model of membrane transport in the dense barrier layer and identify the problem with the constant coefficients’ assumption resulting in the occurrence of “Breakthrough” mode. Our derivation recovers the Spiegler-Kedem-Katchalsky equations in the dilute solution limit, albeit with hydraulic permeability dependent on the local solute concentration in the barrier layer. Taking into account this dependence, necessary for preserving the detailed force balance in the barrier layer, eliminates the existence of the “Breakthrough” mode.