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# Electrokinetic Transport and Joule Heating: Impacts On Microfluidics And Soil Remediation Concentrations

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This study explores how electroosmosis, and buoyancy forces affect flow regimes in electrokinetic systems within rectangular capillaries as well as concentration profiles. It focuses on how the velocity field is shaped by these forces under varying temperature and non-symmetric conditions due to uneven wall convection. The advective impact of Joule heating and convection on solute migration is investigated. Understanding which force dominates and how non symmetric environments influence flow regimes and dispersion is crucial for designing efficient electrokinetic devices and for cleaning protocols. By using generalized (Robin) boundary conditions and identifying a skewness parameter R2, the study helps predict flow reversal behavior and mixing issues affecting design performance based on system parameters and protocols.

Using fundamental analysis, the researchers apply generalized flux (Robin-type) boundary conditions to the heat transfer within the capillary system. Then, the Navier-Stokes equation was solved for the case of buoyancy forces limited by the skewness parameter $R^2$. Finally, the Molar species Continuity equation solution yielded concentration profiles for different scenarios of $R^2$ values and Joule heating. In all these cases, analytical methods for advanced differential equations were applied with excellent results. The area averaging method was applied to solve the molar species continuity equation for the advective case. The derived mathematical model is reported, and several illustrative results are depicted for simulation and analysis of cases. A family of scenarios was obtained for even and uneven wall convection captured in the skewness parameter R2. Also, limiting scenarios were found and reported for cases with insulation and uneven environments. Reverse flow conditions are reported with mixing impact on the concentration profiles. This study extends the analysis of the Joule heating phenomenon to the mass transport domain. The significance is that temperature developments will no longer be seen as a process complication but a key design factor for making electrokinetic remediation more effective and predictable.