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Dipolic MAR "Bubble" Inside Confined Brine Formation or Floating "Lens" on Top of Unconfined Saline Aquifer

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ABSTRACT
In desert environments as Oman and Turkmenistan, MAR sites are often characterized by high salinity of the ambient target aquifer (ATA) and intensive evaporation (Kunin, 1959). We present mathematical modeling of two scenarios: 1) injection-abstraction of fresh (tertiary treated or desalinated) water through two horizontal wells into a confined ATA containing a pristine brine and 2) infiltration from a surface pond of "takyr" type (mild topographic depression of desert surface, with a cake of fine and cracked silty sediments, Babaev, 1999) into an unconfined saline ATA. A fresh water "bubble" bounded by a sharp interface and a UFO-shaped lens capped by a phreatic surface and subtended by a sharp interface are formed in the two corresponding scenarios. Our analytical solutions for steady, 2-D and axisymmetric Darcian flows of fresh water interfaced by stagnant saline water utilize two types of mathematical dipoles: combination of a line sink and source (Strack, 2017) and superposition of a Tothian distributed sink and source. For 2-D dipoles, the theory of holomorphic functions is used (conformal mappings and the Keldysh–Sedov representations of characteristic functions via singular integrals, Kacimov et al., 2018). Explicit closed-form expressions for the interface, flow net, isohypses, magnitudes of the Darcian velocity and Riesenkampf's resultant force (determining stability of the ATA skeleton against heaving, suffusion, colmatage and other deleterious phenomena) are obtained and discussed. MT3DMS and SEAWAT are also used for delineation of isoconcentric lines, which qualitatively corroborate the analytical solutions in delineation of the "bubble". For axisymmemtric floating lenses, which are partially recharged from the "takyr" bed and partially exfiltrate to the vadose zone due to intensive evapotranspiration, U-turn topology of fresh water circulation is similar to the 2-D case of Strack (1978). For the Dupuit-Forchheimer approximation, a boundary value problem for an ordinary differential equation in terms of the Strack potential is explicitly solved. The total volume of fresh water circulating within the lens is evaluated. Constant MAR and evaporation rates, as well as evaporation linearly decreasing with depth of the phreatic surface are considered.