Abstract

Saltwater intrusion (SWI) in coastal aquifers is a critical hydro-environmental problem. The intrusion of saltwater in freshwater aquifers occurs due to variable-density flow in porous media. The conceptual understanding of saltwater intrusion dynamics is important from the aquifer management point of view. The current research quantifies the influence of beach slope and tidal conditions on saltwater dynamics in single and multilayered porous media. A series of experiments were performed in a 2*D Sand Box Model* (longitudinal & vertical). Ten experimental cases (5 + 5) were considered corresponding to single-layered porous media under static and tidal saltwater side boundary conditions. Similarly, Ten experimental cases were considered corresponding to multilayered porous media. Locally available *Clean Sand* was utilized as aquifer material in two experimental cases. However, Grade-I IS Sand was used for all other cases (20 experiments). *Bentonite* was used for the low permeability layer. *Rohdamine B* was utilized as the saltwater tracer. Time-varying porewater pressure values and images were recorded/captured during the experiments. Experimental and numerical analyses showed that the movement rate and volume of the saltwater wedge (i.e., saltwater-freshwater interface toe length) decrease with the increase in beach slope (e.g., $\alpha = 15^0$ to $\alpha = 30^0$). The fingering effect was prominent for flatter slopes. A G-Channel (of R-G-B) based image analysis technique was utilized to identify the saltwater-freshwater interface and concentration gradient from the experimental images. The 50% concentration isolines obtained from the numerical simulations were matched with the interfaces obtained from the image analysis. A narrow mixing zone was observed for the current set of experiments. Upper saline plume (USP) developed for all experimental cases for unconfined layer in single and multilayered systems under tidal saltwater side boundary conditions. The extent of the upper saline plume was dependent on the freshwater flux. The vertical SGD gap (ζ_0) decreases with an increase in beach face slope, whereas the SWI toe length increases. Tracer injection technique was utilized to identify the Submarine groundwater discharge (SGD) pathways. Non-dimensional groups were also identified for both tidal and static conditions. The saltwater-freshwater interface toe length and submarine groundwater discharge gap values depend on beach slope. Flow stability was determined on the basis of Rayleigh number ($R_a^\star = 150$ to 250 or 750).