Helium, radon and radiocarbon studies on a regional aquifer system of the North Gujarat–Cambay region, India

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Abstract

The study reports the age evolution of groundwater as it flows from the recharge area through a regional alluvial aquifer system in North Gujarat–Cambay region in western India. Radiocarbon (\(^{14}\)C), \(^{4}\)He and \(^{4}\)He/\(^{222}\)Rn dating methods have been employed. Sediments from a drill core in the Cambay Basin were also analysed for uranium (U) and thorium (Th) concentrations and the measured values have been used to estimate the \(^{4}\)He and \(^{222}\)Rn production rate for groundwater age calculations. Additionally, factors controlling the distribution of \(^{222}\)Rn, \(^{4}\)He and temperature anomalies in groundwater, vis-à-vis their relation to the tectonic framework and lithology of the study area, have also been examined.

The multi-isotope study indicated a reasonable correspondence in groundwater age estimates by the three methods employed. The groundwater \(^{14}\)C ages increased, progressively, in the groundwater flow direction: from the foothills of Aravalli Mountains in the east, and reached a value of ~35 ka towards the region of lowest elevation, linking Little Rann of Kachchh (LRK)–Nalsarovar (NS)–Gulf of Khambhat (GK) in the western part of the study area. In this region, groundwater ages obtained for free flowing thermal wells and springs employing \(^{4}\)He and \(^{4}\)He/\(^{222}\)Rn systematics are in the order of million years. Such anomalous ages are possibly due to enhanced mobilisation and migration of ‘excess helium’ from hydrothermal circulation vents along deep-seated faults. Excluding such anomalous cases and considering all uncertainties, presently estimated \(^{4}\)He and \(^{4}\)He/\(^{222}\)Rn groundwater ages are in reasonable agreement with \(^{14}\)C age estimates in the Cambay Basin for helium release factor (\(A_{\text{He}}\)) value of 0.4 \pm 0.3. The \(^{4}\)He method also indicated west-southwards progression of groundwater ages up to ~100 ka beyond the Cambay Basin.

Large ‘excess helium’ concentrations are also seen to be generally associated with anomalous groundwater temperatures (>35 °C) and found to overlie some of the basement faults in the study area, particularly along the east and the west flanks of the Cambay Basin. Groundwater \(^{222}\)Rn activities in most of the study area are 800 \pm 400 dpm/l. But, a thermal spring at Tuwa on the east flank of the Cambay Basin, having granitic basement at shallow depth, recorded the highest \(^{222}\)Rn activity (~63,000 dpm/l).

1. Introduction

Determining the age evolution of groundwater as it moves in an aquifer from the recharge area to a distant discharge location is still a challenging task for hydrogeochemists. Sampling locations are often randomly scattered over an area where water from an aquifer is pumped from various depths or where springs bring...