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HYDROLOGICAL AND GEOCHEMICAL ASPECTS OF SINKHOLES' FORMATION ALONG THE DEAD SEA COASTAL AREA

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ABSTRACT

In the past decade, hundreds of sinkholes have developed along the shore of the Dead Sea (DS), posing a threat to life and property and hampering local building and development. The formation of the sinkholes is a dynamic process resulting in the appearance of new sinkholes at unexpected sites. The sinkhole's size can reach 10 m in diameter and in depth.

The formation of the sinkholes is a karst feature occurring due to the following processes: The continuous lowering of the water level in the DS during the past thirty years has caused rapid changes in hydrogeological conditions of the near-shore subsurface. Following a decline in the groundwater table, and a change in the depth of the fresh-saline interface, a subsurface salt layer came into contact with relatively fresh water. The source of this water is probably in a confined aquifer below the salt layer, ascending through tectonic faults or cracks. These cracks probably form due to differential compaction of clay layers as a result of the decrease in groundwater level. The compaction is also evident in surface subsidence, observed by satellite images (InSAR method). Subsequently, a partial dissolution of the salt occur and the formation of caverns in the subsurface. The ceilings of the caverns eventually collapse together with the overlying unconsolidated sediments into the empty spaces. This process ends in the formation of sinkholes on the surface. Other mechanisms of sinkhole formation are also considered, some of which may occur simultaneous with the dissolution mechanism.

The present research involved hydrological, geophysical and geochemical tools in order to test the above mechanism. Geophysical methods, including seismic refraction, allow the recognition of the salt layer (seismic velocity of about 3000 m/sec), which is a necessary condition for the formation of sinkholes on the surface. Indeed, in the northern part of the DS area, no evidence was found for the salt layer in the subsurface, and no sinkholes were observed on the surface. The seismic reflection surveys indicated that several faults occur at the elongated sites of sinkholes, probably allowing flow of groundwater near the salt layer. The TDEM results implied that the lower sub-aquifer, below the salt layer is filled with less saline groundwater, capable of dissolving salt. Most of these geophysical data was confirm in drilling conducted in several parts of the DS coast.

Preliminary hydrological simulations were run, using the USGS SUTRA code, taking into account the change in the DS levels and subsequent changes in the groundwater system. The simulations show that the drop in 20 m in the DS level in the last 30 years could be responsible for movement eastward of the interface by about 1 km. Such a change would cause the area where sinkholes occur now, which was filled with DS brine, to be partly flushed and the salt layer to be dissolved.

The geochemical properties of groundwater in the DS coastal aquifer give some indications for dissolution of salts. This is best exhibited in the Na/Cl ratio of groundwater obtained in the vicinity of the salt layer (0.4-0.5 compare to 0.25-0.30 of the DS brine). The Na/Cl ratio increases due to dilution of DS type brine by fresher groundwater and later dissolution of the salt layer.

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