Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27996

Hydrogeochemistry of Mineral Precipitates and Aerosol Release from Natural Brines in Hessian Graduation Towers

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Graduation towers in Germany, Poland and Austria are significant in their ability to produce sea-like microclimate relevant for treatment of respiratory diseases, increase microbial diversity and decrease air temperature. This study focuses on the quantification of mineral precipitates formed due to brine water evaporation through hydrogeochemical modelling using PhreeqC and the analysis of aerosols as a byproduct of the graduation process at three spa sites in Hesse, Germany. Minerals like Halite, Gypsum, Calcite and amorphous phases are observed to be formed at different sites under different rates of evaporation as a function of brine water concentration. The graduation process increased the concentration of the brine water by a maximum of 88% with concentration of NaCl ions in the water from the towers ranging from 15-36 g/l. Stimulated precipitation experiments resulted in the biggest graduation tower under consideration, tower 5, Bad Nauheim, (155 m length x 12.5 m height) in a production of 15.5 kg precipitates per day as compared to 0.5 kg from a small graduation wall in Bad Soden-Salmünster (13 x 3 m). Stimulated additional climate change related temperature increases of 2.5° C resulted in 1.87% decrease in the precipitates formed per year in Bad Nauheim and a 0.06% increase in precipitates formed in Nidda-Bad Salzhausen. CO2 degassing at increasing atmospheric pCO_2 scenarios was not observed to produce a significant effect on the quantity of mineral precipitates formed. A new aerosol sampling method in the area using electrical conductivity as indicator for aerosols capture in Petri dishes filled with deionised water worked fine. Electrical conductivity increased dependent on distance to the graduation tower, exposure time, wind direction and speed to 9,600 µS/cm. A maximum of 522 kg/d of aerosols are estimated to be released from a large graduation tower into the atmosphere. With a share of about 90%, NaCl dominates aerosols composition, simulating aerosols in coastal environments and making such structures beneficial for human health.