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Tracing altitudinal changes in microbial life and organic carbon source in soils of the Atacama Desert

Wulf Amelung, Roland Bol, Tibor Dunai, Barbara Fuentes, Andrea Jaeschke, Eva Lehndorff, Claudia Knief, Erwin Klumpp, Stephanie Kusch, Ramona Moerchen, and Janet Rethemeyer

Bonn, Bonn, Germany (wulf.amelung@uni-bonn.de)

The hyper-arid soils of the Atacama frequently served as model systems for tracing life under extreme dry conditions such as on Mars. Plants rely on fog moisture (coastal zones) or on irregular rainfalls (mainly north-eastern part), which are controlled by the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) and vary with latitude and altitude. We therefore hypothesized that traces of life in the Atacama Desert are patchy, but nevertheless also follow latitudinal and altitudinal gradients. To test this hypothesis, we sampled surface soils (0-10 cm) along an altitude transect in the region of Quebrada Aroma spanning from the arid Precordillera of the Andes towards the hyper-arid core of the desert (1,300 m to 2,700 m a.s.l). We assessed the contents of organic carbon (OC), total nitrogen (N), extractable total S as well as of n-alkanes and n-fatty acids for tracing organic residues in these soils. We screened the element composition in order to derive information on potential soil formation processes along these gradients. In addition, we analyzed living microbiota using a combination of cultivation-dependent and independent approaches and we performed DNA extraction for amplification of the 16S rRNA gene fragments with subsequent analyses of PCR products by denaturing gradient gel electrophoresis. Additional information on bacterial and archaeal community composition was obtained from phospholipid fatty acids (PFLA) and glycerol dialkyl glycerol tetraethers (GDGTs).

OC contents in the surface soils increased from the hyper-arid core in the desert to wetter sites at higher altitudes and presence of sparse vegetation. The abundances of aliphatic lipid biomarkers (short chain n-alkanes, n-fatty acids) increased along the altitudinal transect. Most n-alkanes and n-fatty acids at the drier, lower altitude (1,340 m) were short-chain homologues suggesting a microbial origin, whereas at higher elevation (2,721 m; marginally wetter) more long-chain compounds were present suggesting a larger contribution of plant-derived OC. Ongoing radiocarbon analysis will give further insights into OC sources (old versus young). Living cells were detectable at all sites with a consistent decrease in cell numbers as aridity increased. Lowest cell numbers below the detection limit of 5 CFUs g-1 soil were found at the driest sites. Intriguingly, we did not find pronounced changes in bacterial diversity using cell counting and simple denaturing gradient gel electrophoresis. The distributional patterns of the PLFAs suggest a significantly larger bacterial diversity at the highest, wettest altitude than at the lower, dryer sites. In addition, both archaeal isoprenoid GDGTs and bacterial branched GDGTs were detected in all samples also following the altitudinal trend with similar concentrations at sites located at 2,020 and 2,720 m altitude. These results suggest that several microorganisms are able to survive extreme dryness. The abundance of these organisms spans along an altitudinal gradient that follows the pattern of rare precipitation events, correlating also with the presence of sparse vegetation remains. After cell death, many of these biomolecules are preserved, now offering novel potentials also for tracing the evolution of past life forms from their cell wall remains.