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Bacteria and Archaea on Earth and their abundance in biofilms

Biofilms are a form of collective life with emergent properties that confer many advantages on their inhabitants, and they represent a much higher level of organization than single cells do. However, to date, no global analysis on biofilm abundance exists. We offer a critical discussion of the definition of biofilms and compile current estimates of global cell numbers in major microbial habitats, mindful of the associated uncertainty. Most bacteria and archaea on Earth (1.2×10^{30} cells) exist in the 'big five' habitats: deep oceanic subsurface (4×10^{29}), upper oceanic sediment (5×10^{28}), deep continental subsurface (3×10^{29}), soil (3×10^{29}) and oceans (1×10^{29}).

The remaining habitats, including groundwater, the atmosphere, the ocean surface microlayer, humans, animals and the phyllosphere, account for fewer cells by orders of magnitude. Biofilms dominate in all habitats on the surface of the Earth, except in the oceans, accounting for ~80% of bacterial and archaeal cells. In the deep subsurface, however, they cannot always be distinguished from single sessile cells; we estimate that 20–80% of cells in the subsurface exist as biofilms. Hence, overall, 40–80% of cells on Earth reside in biofilms. We conclude that biofilms drive all biogeochemical processes and represent the main way of active bacterial and archaeal life.