The L.A. Colding Lecture Series

in Environmental Science and Technology

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Life and death in biofilms

Room 011, Building 113
Thursday, January 8th 2009, 15:00

Abstract:

Microorganisms typically do not live as single cells in pure cultures. The vast majority lives in mixed populations, organized in aggregates which are termed "biofilms". They include films at interfaces, flocs (floating films), sludges and microbial mats. They all are aggregates of microorganisms, which have emergent properties in common that only can be developed in aggregated form: they generate a matrix of extracellular polymeric substances which keeps them together, allows for the development of stable, synergistic microconsortia and for intense cell-cell communication. The matrix sequesters nutrients from the environment, prevents washing out of extracellular enzymes and serves as ultimate recycling yard and nutrient source. In this matrix, horizontal gene exchange is facilitated with a vast gene pool present. In biofilms, organisms differentiate rapidly, forming phenotypically different subpopulations with "division of labour", a mechanism which contributes to their ecological fitness. Resistance to biocides is enhanced by a range of mechanisms. On the other hand, strong competition prevails in which elementary attacking and defence strategies evolved, including the formation of antibiotics and bacteriocins. Grazing organisms can limit biofilm growth but this also stimulates ecological fitness. Even programmed cell death is observed, leading to a more porous matrix which allows for better access of nutrients for organisms in the depth of the matrix. Under stress conditions, cells can transform into a viable but not cultivable (VBNC) state which is of relevance for public hygiene because they cannot be detected with the methods designed for their determination but can resuscitate. Biofilms represent the oldest, most abundant and successful form of life on Earth, displaying aspects of multicellularity. Life evolved from biofilms and they are involved in the biogeochemical cycles of all major elements. In biofilms, photosynthesis was developed biofilms they are responsible for the self-purification mechanisms of soils, sediments and water. However, they can occur in the wrong place and time, causing biofouling, microbially influenced corrosion and biodeterioration in technical systems, leading to substantial economical loss and supporting an entire industry dedicated to cleaning and disinfection. In medicine, they are cause of persistent infections and are related to many diseases. In general, biofilms are of fundamental but mostly unaccounted relevance for our life.

Ludvig August Colding was Copenhagen´s city engineer in the period 1857-1886 and designed the city´s water supply system. He chose to base the supply entirely on groundwater. The system´s general layout and many of its details date back to Colding´s era. From 1869-1886, Colding was a professor at the Technical University of Denmark. At the age of 26, he discovered the law of conservation of energy, simultaneously with, but independently of Joule.

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