

Biofilm Microbiology, Control and Release

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Problem

- Water treatment processes are optimized to produce high quality water that deteriorates in the distribution system and premise plumbing. Microbiological issues are often associated with biofilms.



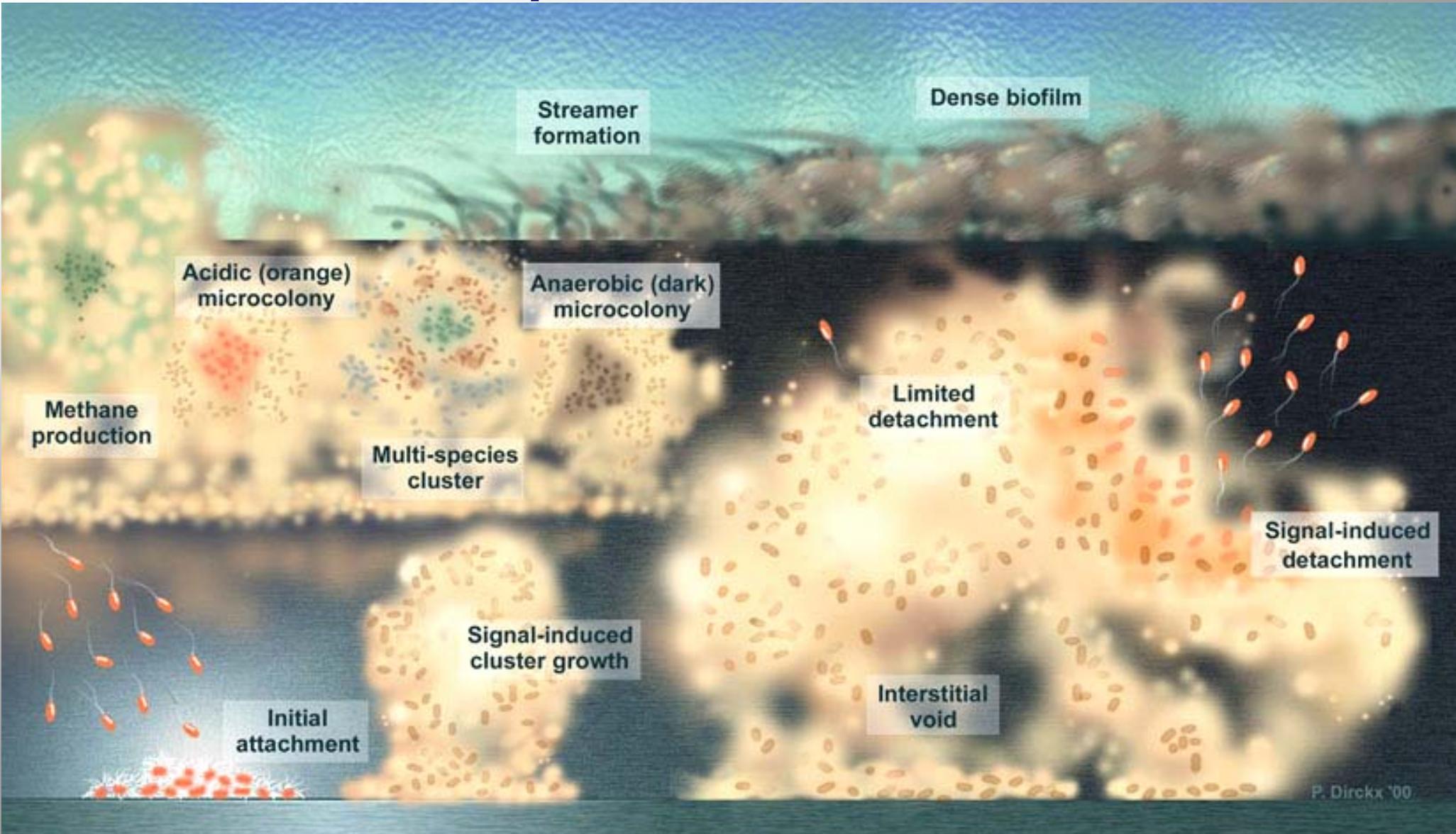
What is a biofilm?

- Cells - bacteria, fungi, algae
- Extracellular polymers
- Trapped organic molecules
- Inorganic compounds



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Biofilms are complex multicellular communities





What organisms are in biofilms?

- Wide variety of bacteria, many unknown
- Generally not of any health concern
- Originate from other places in the environment (source water, soil, etc.)



Organisms of concern

- General heterotrophs
- Coliforms (regulatory)
- Opportunistic pathogens
- Nitrifying organisms (chloraminated systems)



Coliforms in biofilms

- Occur at discrete locations
- Implications for gasket materials, pipe surfaces
- Difficult to find in the field on surfaces



Monitoring of biofilms

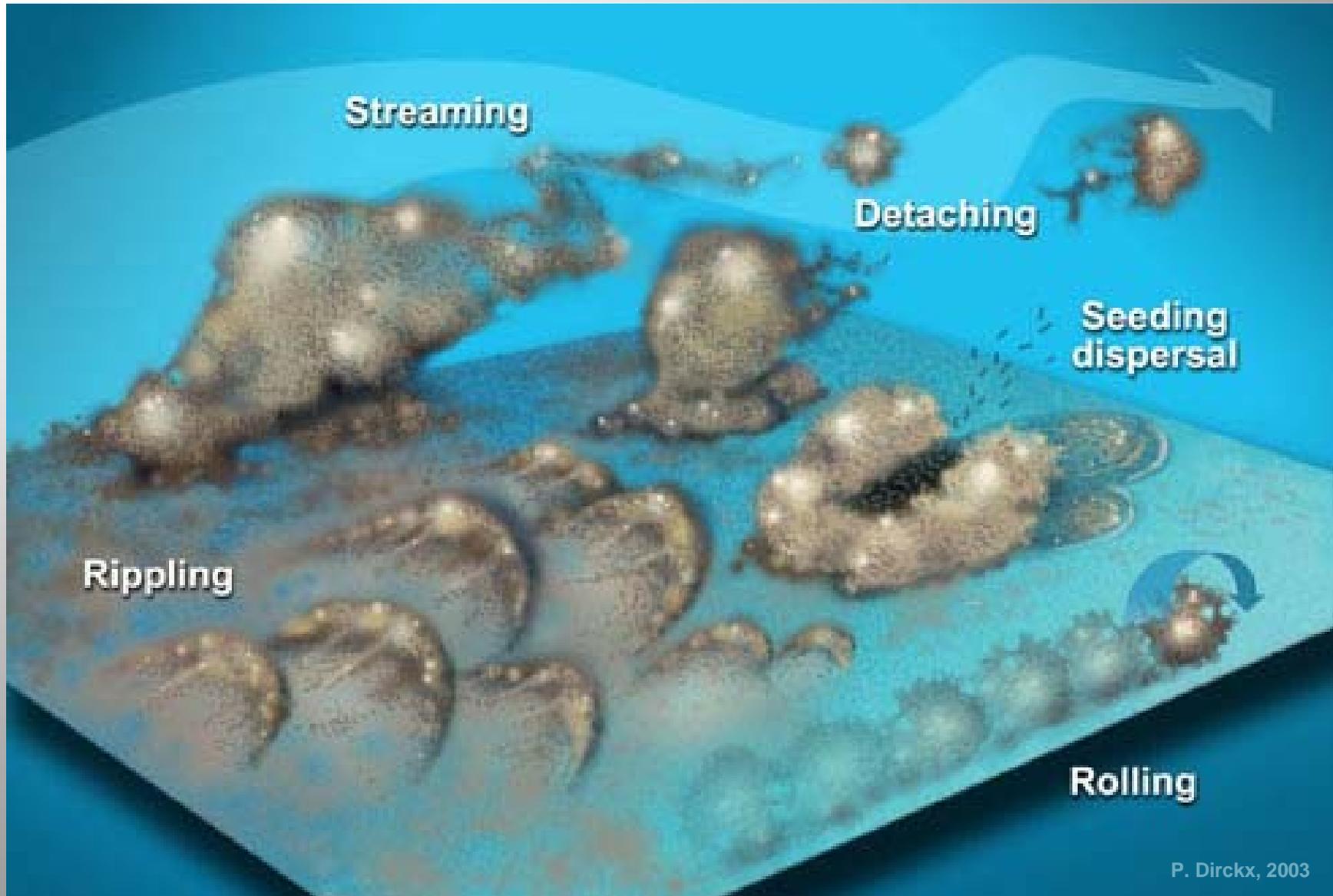
- Reliance on suspended counts in water
- Typical use of plate counts
- Indirect evidence
- Lack of correlation with biofilms



Reliance on suspended counts

- Bulk cells from detached biofilm
- Detachment may be periodic
- Clumped cells underestimate counts
- False security - no suspended cells, still have biofilm

Biofilms are dynamic and resilient





Organisms introduced through:

- Treatment breakthrough
- New materials/installation
- Cross connections/back siphoning
- Other sanitary concerns (tanks, etc.)



Interaction of factors

- Quality and quantity of organics
- Type and concentration of disinfectant
- Type of pipe material and corrosion control
- Flow, temperature, pH, etc.

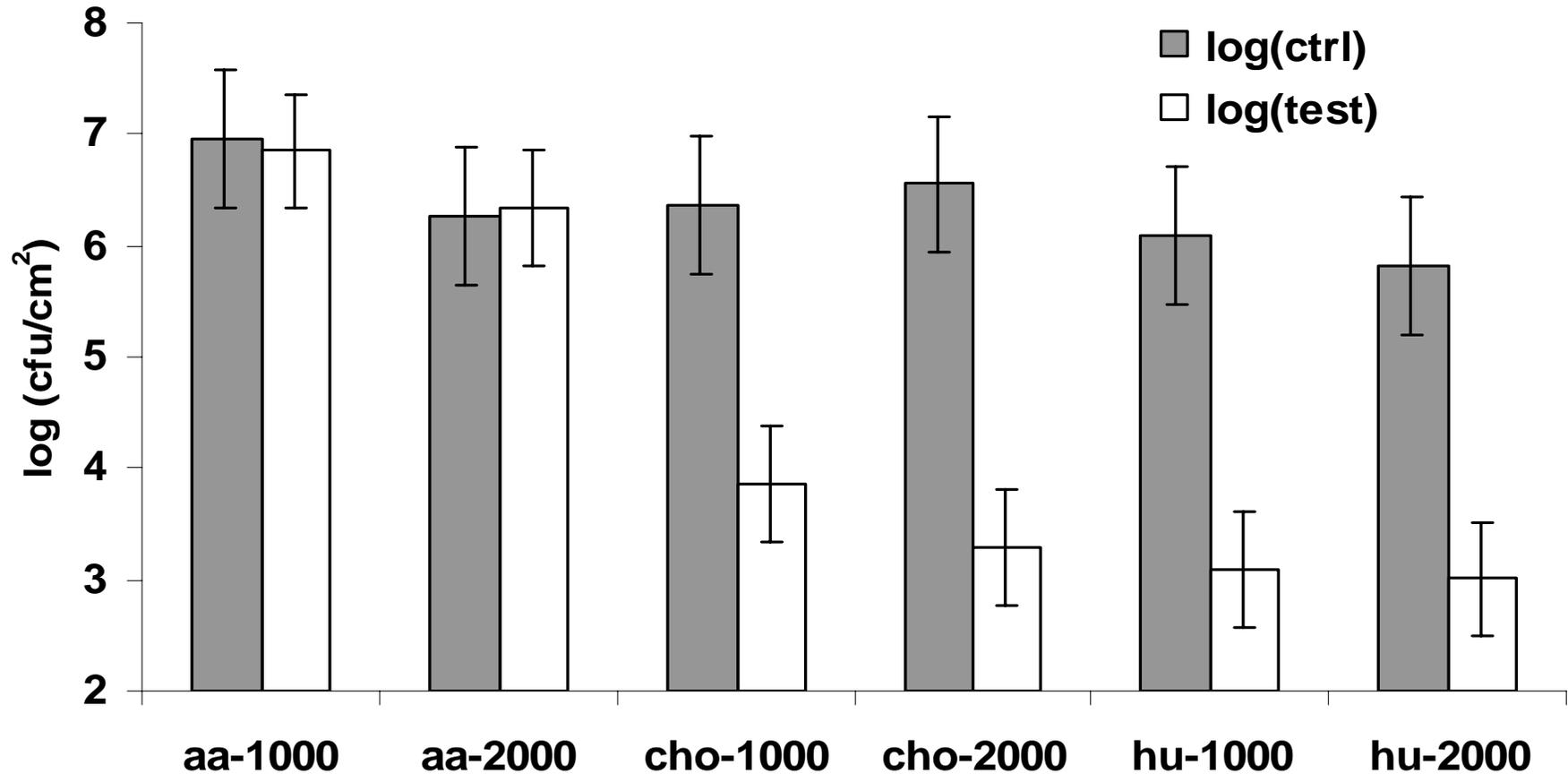
Carbon concentration

- Biofilms grow on very low concentrations of organics
- Preventing growth by eliminating organics generally not feasible
- Can limit growth by decreasing utilizable fractions, BDOC and AOC may not measure everything

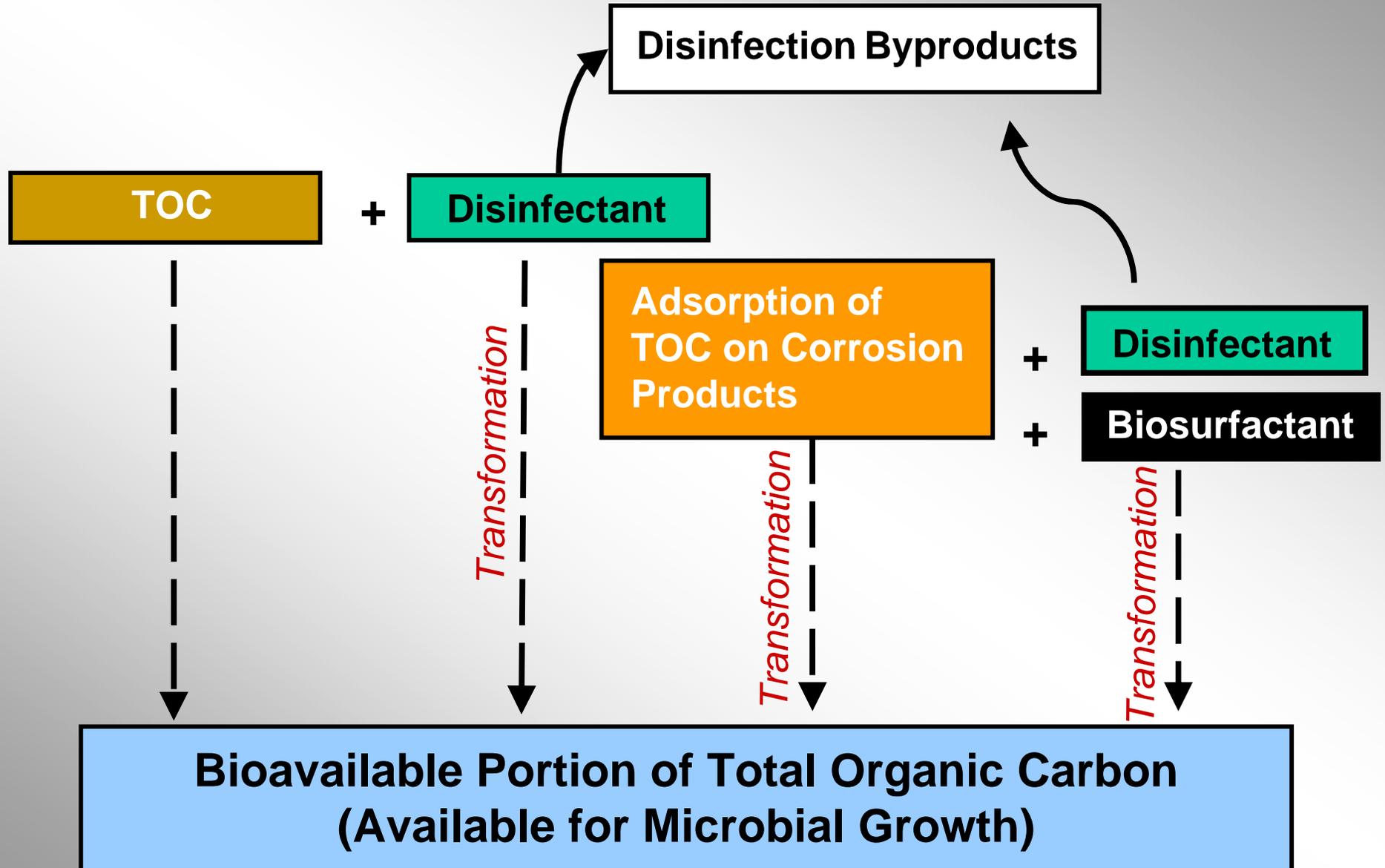
Adsorbed humics



Biofilm Culturable Cell Counts



Biotransformation pathways of Total Organic Carbon





Disinfectant effects on biofilms

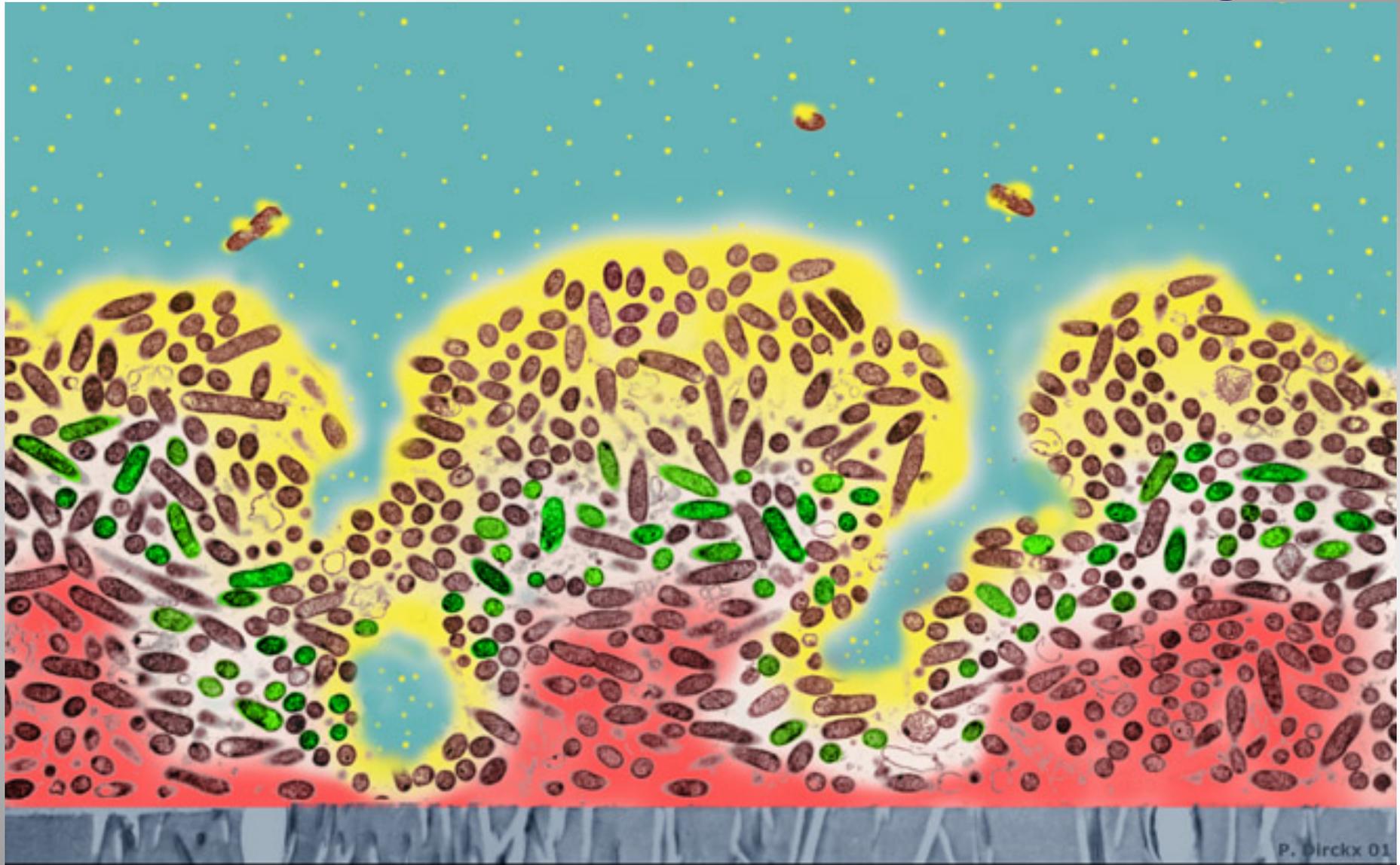
- Cannot be predicted using suspended cells
- Cannot extrapolate results in bulk to that in biofilms
- Surfaces important, impact effect
- May select for certain organisms



Biocide “resistance”

- ca. 1000 x more than suspended cells
- Regrowth in short time periods
- Detachment different than killing

Biofilm resistance to antimicrobial agents



Slow Penetration

Resistant Phenotype

Altered Microenvironment

Disinfectants: chloramines vs chlorine

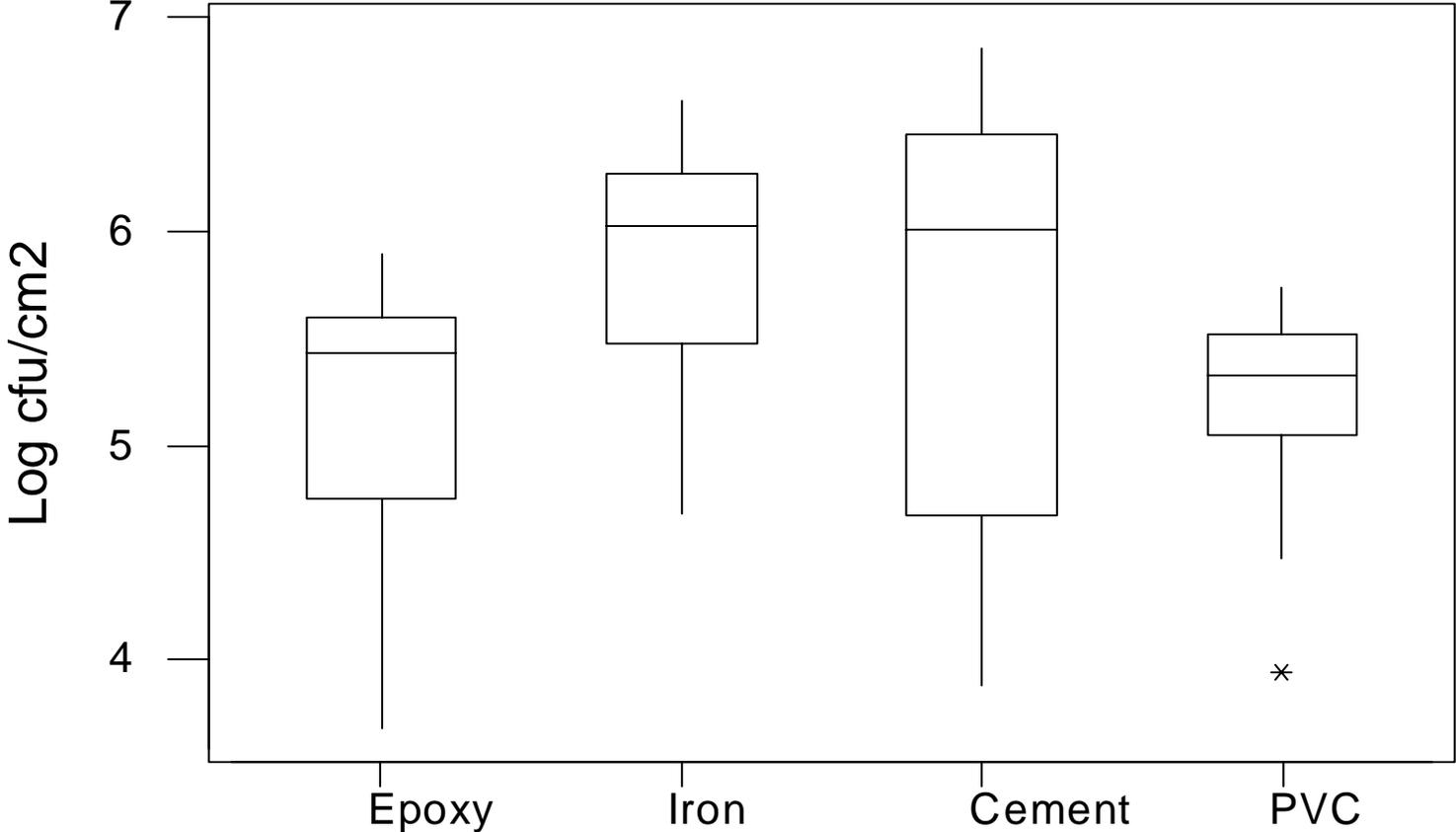
- Early data suggested better microbial control in DS; HPC and coliforms with chloramines but not universally true
- May be of benefit where corrosion occurring
- Balance in controlling opportunistic pathogens?



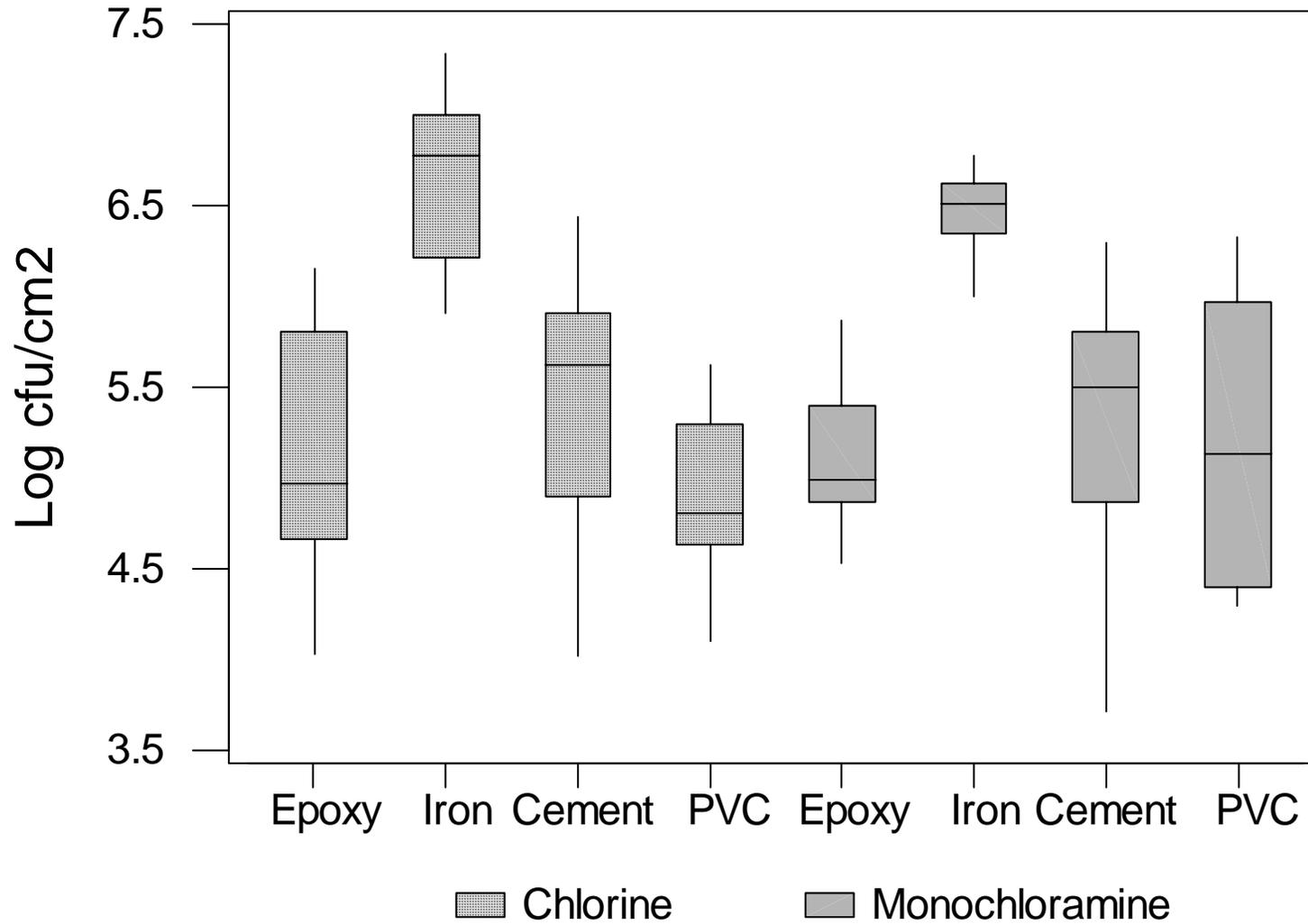
Impact of pipe/plumbing materials

- General consensus that corroding iron increases regrowth
- Conflicting information and misconceptions on copper control of organisms
- Possibility of leaching of organics from plastics/PVC

HPC biofilm densities in phase 1.



HPC biofilm densities in phase 4.





Corrosion control

- Disinfectants influence corrosion
- Corrosion control impacts disinfectant - regrowth interactions
- Interactions depend on corrosion control method, pipe material, disinfectant, water chemistry



Nitrification

- May be implicated in corrosion because of pH change
- Can occur in plumbing systems
- Impact on disinfectant residuals
- Impact on HPC counts



Interacting water quality requirements

- TCR
- DBPs
- Maintain residual
- Control corrosion/LCR



Universal rule(s)

- Biofilms are difficult to control
- No solution is acceptable for all situations