Impact of DOC on biological stability in drinking water distribution systems

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Drinking water distribution without residual disinfectant in the Netherlands

Historical background

• Years 1970: discovery of disinfection by-products and health effects

• Years 1990-2000: shift of main water disinfection step from chlorine to ozone and UV in NL distribution without maintaining residual disinfectant

• 2006: implementation of strict DBP regulations in the Netherlands: TTHM < 25 µg/L
Implications for drinking water distribution

How to limit bacterial growth during water distribution without residual disinfectant?

• Requires to produce biological stable water using extensive water treatment:

  ⇒ limit available nutrients for bacterial growth:
  - C source: part of DOC can be consumed by bacteria for growth
  - N source: e.g. NH4, NO3, N-bound organic compounds
  - P source: e.g. PO4, P-bound organic compounds

  ⇒ Limit release of particles in the distribution system

• Requires well-designed systems and good maintenance of distribution systems

  ⇒ avoid recontamination, long residence times, and temperature hot-spots
ClO$_2$ dosage: $\sim$0.01 mg/L at WTP effluent
Not maintained in distribution
PWN treatment plants and distribution areas
Characteristics of NOM in the 3 WTPs

Assimilable organic carbon (AOC) is a tiny fraction of TOC. This is the fraction that bacteria can use for growth.
Characteristics of NOM in the 3 WTPs

The 3 WTPs produce water with same TOC but - different NOM composition - different AOC concentration
Detection of priority areas

Highest ATP values in area supplied by WTP Andijk, especially in specific area

⇒ Confirms known problems:
- past customer complaints on turbid water
- need for regular flushing program
Microbial regrowth during water distribution

**Effect ClO\textsubscript{2} dosage:** biofilm detachment

Progressive regrowth in transport sections when disinfectant not available

**Graph:**
- **A** to **B**: transport pipe (800-900 mm, 20 km)
- **B** to **C**: transport pipe (800-900 mm, 20 km)
- **C** to **D**: transport pipe (500-700 mm, 10 km)
- **D** to **E**: distribution area (40-300 mm, 0.5 km)

**Intact cells (cells/mL):**
- **A**: 60000
- **B**: 20000
- **C**: 70000
- **D**: 70000
- **E**: 70000
- **F**: 70000

**Legend:**
- A: Treatment
- B: Reservoir
- C: Transport pipe
- D: Distribution area
- E: Reservoir
- F: Treatment

**Text:**
- Microbial regrowth during water distribution
- Effect ClO\textsubscript{2} dosage: biofilm detachment
- Progressive regrowth in transport sections when disinfectant not available
Nutrients availability during water distribution

Effect \( \text{ClO}_2 \) dosage: increase inavailable nutrients

Effect bacterial growth: consumption of nutrients

Clear link between available nutrients and bacterial growth
Sediments build up during water distribution

Not only bacterial growth in bulk water, but also build-up of sediment occur during water transport and distribution.
Sediments build up during water distribution

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Sediment composition in distribution system

Sediment composition (location E)

- asellus feces: 40-60%
- detritus: 50-80%
- other: 0-20%

sediments composed at 80-90% of organic material
Food chain in distribution systems

Dissolved nutrients (AOC)

Bacterial growth

Extra nutrients (particulate)

Sediment formation

Growth of small invertebrates

Growth of large invertebrates

Feces production, die-off, molts, etc.
conclusions

• Organic matter in drinking water have impact on bacterial growth in drinking water distribution system

• The type and composition of different NOM compounds is determining factor for growth

• The exact dissolved and particulate compounds playing a role in bacterial growth and sediment build-up are still unknown and unexplored.

• Dissolved nutrients initiate food chain, which results in production of particulate nutrients and further promote sediment build-up.
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