The use of ultrafiltration in the public drinking water supply in Germany

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The use of UF in the public drinking water supply in Germany - Overview

- DVGW – TZW - what is it?
- Drinking Water Supply in Germany
- Membrane filtration plants in Germany
- Recommendations for design, operation, ...
- Case studies
- New plant concepts
- Conclusions
DVGW – TZW

- Association of German Gas and Waterworks since 1859, independent, non-profit, technical-scientific
- Members (gas and water utilities, public authorities, companies, individuals
- Fields of work: Regulation, Standardisation, Testing, Certificates, Research and Development, Know-how-transfer, dissemination
- TZW = part of DVGW, center for applied research (technology, analytical chemistry, microbiology, environmental biotechnology and site management, groundwater modelling, corrosion, material testing)
Size structure of public water supply

6,974 water utilities

- < 0.1 Mio. m³/a: 36.1%
- 0.1 - 0.5 Mio. m³/a: 34.5%
- 0.5 - 1 Mio. m³/a: 12.3%
- 1 - 5 Mio. m³/a: 25.3%
- 5 - 10 Mio. m³/a: 11.6%
- > 10 Mio. m³/a: 46.7%

- Number of water supply utilities
- Amount of supplied drinking water
Produced Drinking Water by the Public Water Supply in Germany

Total water demand $5,4 \cdot 10^9 \text{ m}^3/\text{a}$

127 L per capita per day
Raw water sources in Germany

- Ground water: 65%
- Surface water: 26%
- Spring water: 9%
- Bank filtrate: 13%
- Lakes and dams: 12%
- Rivers: 1%
Local distribution of Raw Water Sources in Germany
MF/UF-plants in Germany
(1.3.06)

Plant capacity
- 1-10 m³/h
- 10-50 m³/h
- 50-250 m³/h
- 250-1000 m³/h
- >1000 m³/h
Production capacities of UF-plants

- Number of UF-plants in Germany (Σ 91):
  - 1-10 m³/h: 34
  - 10-50: 29
  - 50-250: 35
  - 250-1000: 7
  - >1000: 1

- Plant capacity, m³/h (Σ 14,343 m³/h):
  - 1-10 m³/h: 846,9
  - 10-50: 106,7
  - 50-250: 2628
  - 250-1000: 4761
  - >1000: 6000
Origin of raw water for UF-plants

Number of UF-plants in Germany (Σ 91)

- Quelle: 4
- Talsperre: 17
- Brunnen: 49
- Uferfiltrat: 14
- n.n.: 7

Plant capacity, m³/h (Σ 14,343 m³/h)

- Quelle: 834
- Talsperre: 1,387,5
- Brunnen: 1,207,6
- Uferfiltrat: 3,169,5
- n.n.: 7744
Membrane types installed in UF-plants

number of UF-plants in Germany (Σ 91)

plant capacity, m³/h (Σ 14.343 m³/h)
Development of plant installations

plant capacity (MF/UF), m³/h

- **MF/UF-plants**
- **total MF/UF-plants**

Year:
- 1998
- 1999
- 2000
- 2002
- 2003
- 2004
- 2006
Integration of membrane filtration in the treatment process

- MF/UF (5%)
- MF/UF + disinfection (14%)
- MF/UF + post treatment + disinfection (5%)
- pretreatment + MF/UF + disinfection (14%)
- pretreatment + MF/UF + post treatment + disinfection (14%)
- n.n. (48%)

Results of a survey among 91 MF/UF-plants
Hygienic Safety of MF/UF-plants for drinking water supply (DVGW, 04/2006)

- Treatment of microb. contamin. waters with disinfection
  - Filtrate quality < 0,2 FNU
  - With MF/UF requirements are always kept

- Treatment of microb. contamin. waters without disinfection
  - Only membranes with a virus removal of > 99.99%
  - Proof of 99,99 % virus removal by the manufacturer of the membranes
  - Quality management during production of membranes and modules
  - Online-monitoring of membrane integrity is recommended
  - Direct or indirect online-monitoring of particles in the virus size range is not available
  - Not enough long term experience of UF operation available

Recommendation:
if particle removal by UF is the only treatment step
=> a disinfection should be provided
Technical Rule W 213-5

- Definitions
- Requirements
  - for membranes
  - for modules in plants
- Recommendations for design and operation, monitoring …

- Rohwasser = Feed
- Filtrat bei Mikro-/Ultrafiltration (Permeat bei Umkehrosmose/Nanofiltration)
- Spezifische Flächenbelastung (Filtratfluss, Flux) = Filtratmenge / Membranfläche (L/m²/h)
- Transmembrandruck = mittlerer Feeddruck - Filtratdruck
- Permeabilität (L/m²/h/bar) bei 20°C = Flux / TMP
- Fouling (Verblockung) = Verminderung der Durchlässigkeit
- Ausbeute = Filtratmenge bezogen auf Rohwassermenge
- Dead-End- bzw. Cross-Flow-Betrieb
- Trenngrenze - Porenweite oder Rückhalt (MWCO = molecular weight cut off)
monitoring / integrity

- control of operation data regularly
- turbidity measurement continuously
- analysis of bacteriology every 1 or 2 weeks
- particle counting (1-100 µm) UF-filtrate every now and then
- integrity testing with pressure decay once a year
Steps to establish UF

- Monitoring of raw water quality (turbidity, microbiology, phys.-chem. parameters, dissolved organic compounds)
- Determination of site conditions
- Elaboration of treatment concept
- Pilot plant investigations
  - worst case raw water quality and representative time
  - What is the most suitable membrane system?
  - Where should UF-plant be integrated?
  - Find out operation conditions to be used as basic data for the large scale application
  - Find out optimal conditions for backwash and chemical cleaning
Evaluation of optimal backwash conditions

The diagram illustrates the change in transmembrane pressure (TMP) and flux over time during backwash operations with acid/base and NaOCl. The yellow marker indicates a chemical cleaning event. The graph shows the filtration interval and the backwash with acid/base and NaOCl.
Long term behaviour of UF-membranes

- backwash with filtrate + H₂O₂ (sometimes NaOCl)
- chemical cleaning
- mean TMP at 20°C
- filtrate + NaOCl
- filtrate + acid/base
- dosing of flocculant
- backwash water demand, %
- backwash water demand, %

1999 2000 2001 2002 2003 2004 2005 2006

TMP (20°C) with 60 m³/h, mbar

- 0
- 5
- 10
- 15
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100
- 110
- 120
- 130
- 140
- 150
- 160
- 170
- 180
- 190
- 200
- 210
- 220
- 230
- 240
- 250
- 260
- 270
- 280
- 290
- 300
- 310
- 320
- 330
- 340
- 350
- 360
- 370
- 380
- 390
- 400
Influence of backwash chemicals

Skid 4  Skid 1  Skid 3  Skid 2

backwashes with H₂O₂  backwashes with H₂O₂  backwashes with H₂O₂

mean flux (45 L/m²/h)

backwash with Cl₂
Long term behaviour – influence of chemically enhanced backwash

- permeability (20°C)
- chemical cleaning
- dosing of flocculant
- backwash with NaOCl

acid/base-backwash every 12 h
backwash every 8 h
chemical cleaning every 7 h

filtrate backwash every 1.5 h
Characterisation of dissolved organic matter

Hermeskeil 19.10.05

values, µg/L TOC A B C D E F G
raw water 1537 177 87 617 330 153 173 0.58
feed of UF-plant 1308 222 12 437 315 166 156 0.04
filtrate of UF-plant 1217 172 10 435 309 148 142 0.02

A HOC+POC
B polysaccharides
C humic substances
D building blocks
E neutral substances
F low molecular substances
G inorg. Colloids

raw water
feed of UF-plant
filtrate of UF-plant
New UF-plant concepts

- Target group: small-scale systems (0.1 to 10 m³/h)
- Lower level of equipment compared to large-scale plants
- Lower investment costs
- Chemical cleaning / integrity test
  => within service package
- COP: Cleaning out of place
- DVGW/UVM – research project “COP-Membranes”
Examples for COP-UF-plants

2,2 m²  
only forward-flush

6,2 m²  
forward- and backflush

9 m²  
Backwash with filtrate and air / forward- and backflush

50 m² membrane area
Specific investment costs

![Diagram showing specific investment costs with plant capacity vs. investment costs for equipment only for COP, CIP, and NF/UF technologies.](image-url)
Conclusions MF/UF

- Development from R&D to the state of the art
- Increasing operation experiences
- There is still need for
  - optimization of backwash and cleaning processes
    - Influence of raw water quality
    - Difference of membrane systems
  - Research and development of fouling resistant membranes
  - Other applications …