Dead end filtration is not dead

Prof. Dr.-Ing. Franz-Bernd Frechen, University of Kassel

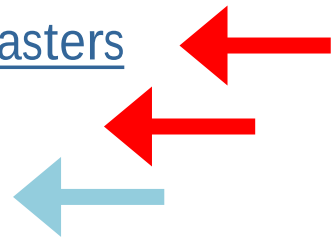
Chair, IWA Specialist Group
"Membrane Technology"

Director of the Institute of Water,
Waste, Environment

Head of the Department of Sanitary
and Environmental Engineering (DESEE)

Deutschland
Land der Ideen
Ausgewählter Ort 2011
Winner 2011 in the category „society"

- Ü the starting point: filtration of surface waters with an **U**ltra **L**ow **P**ressure **U**ltra**F**iltration (**ULPUF**) :
  - Ä for decentralized water supply in emergencies and disasters
  - Ä for decentralized water supply for permanent use
  - Ä for pre-treatment in seawater desalination
- Ü Q & A section
- Ü conclusions & outlook



WaterBackpack "**PAUL**" designed by DESEE:

- Ü at DESEE, **starting 2001**, we designed the **WaterBackpack** called "**PAUL**", a small **membrane ultrafiltration** (**UF**) unit
- Ü membrane area 9.5 m^2
- Ü **1,200 L/d for 400 people**
- Ü weight: 23 kg
- Ü height: 1.2 m
- Ü size: 0.4 m x 0.4 m
- Ü 6 unit fit on a standard Euro-palette

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The **requirements** are:

- Ü No chemicals needed
- Ü No energy needed
- Ü No operation personnel needed
- Ü No maintenance needed
- Ü Absolutely robust
- Ü Instant delivery
- Ü Easily transportable

The **solutions** of the WaterBackpack "**PAUL**":

- Ü No **chemicals** needed – Membrane (A_{mem} 9.5 m^2) to filter pathogens, nominal pore size 40 nm (0.04 µm) (MWCO 150 kDalton)
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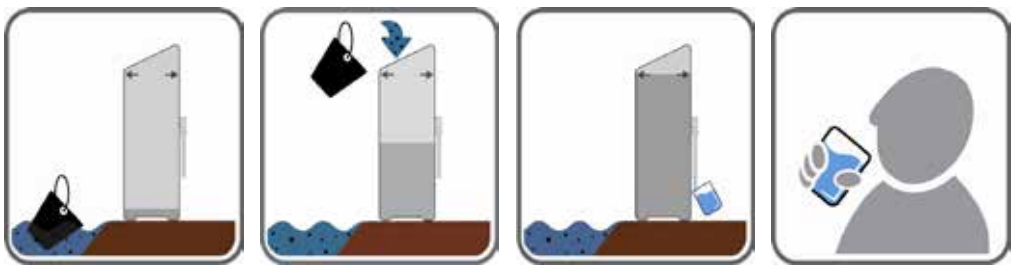

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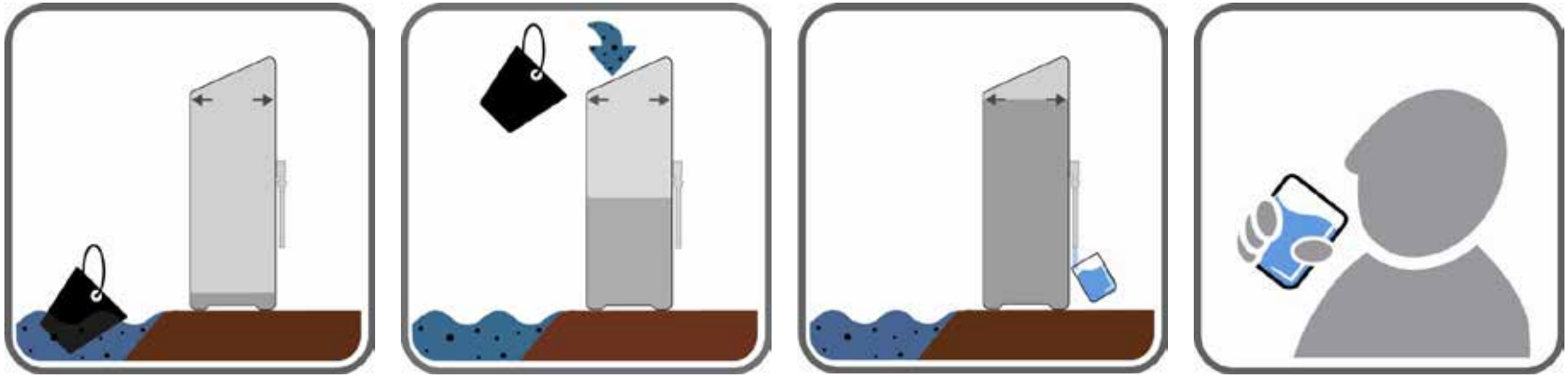
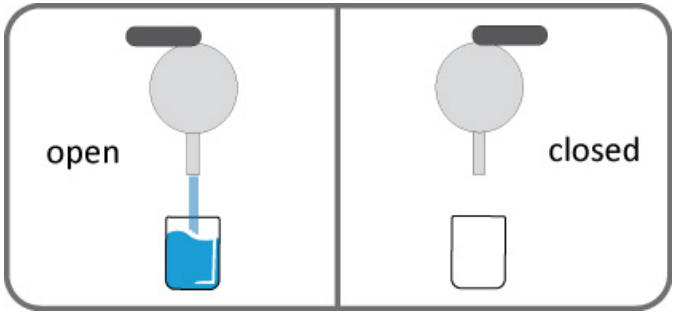
- Ü Easily **transportable** – weighs 23 kg,transport on the back, by bike, by lorry, by helicopter ....

The complete operation manual

Ü no moving parts, no energy, no chemicals, no maintenance , extremely robust, to be operated by anyone – even illiterates



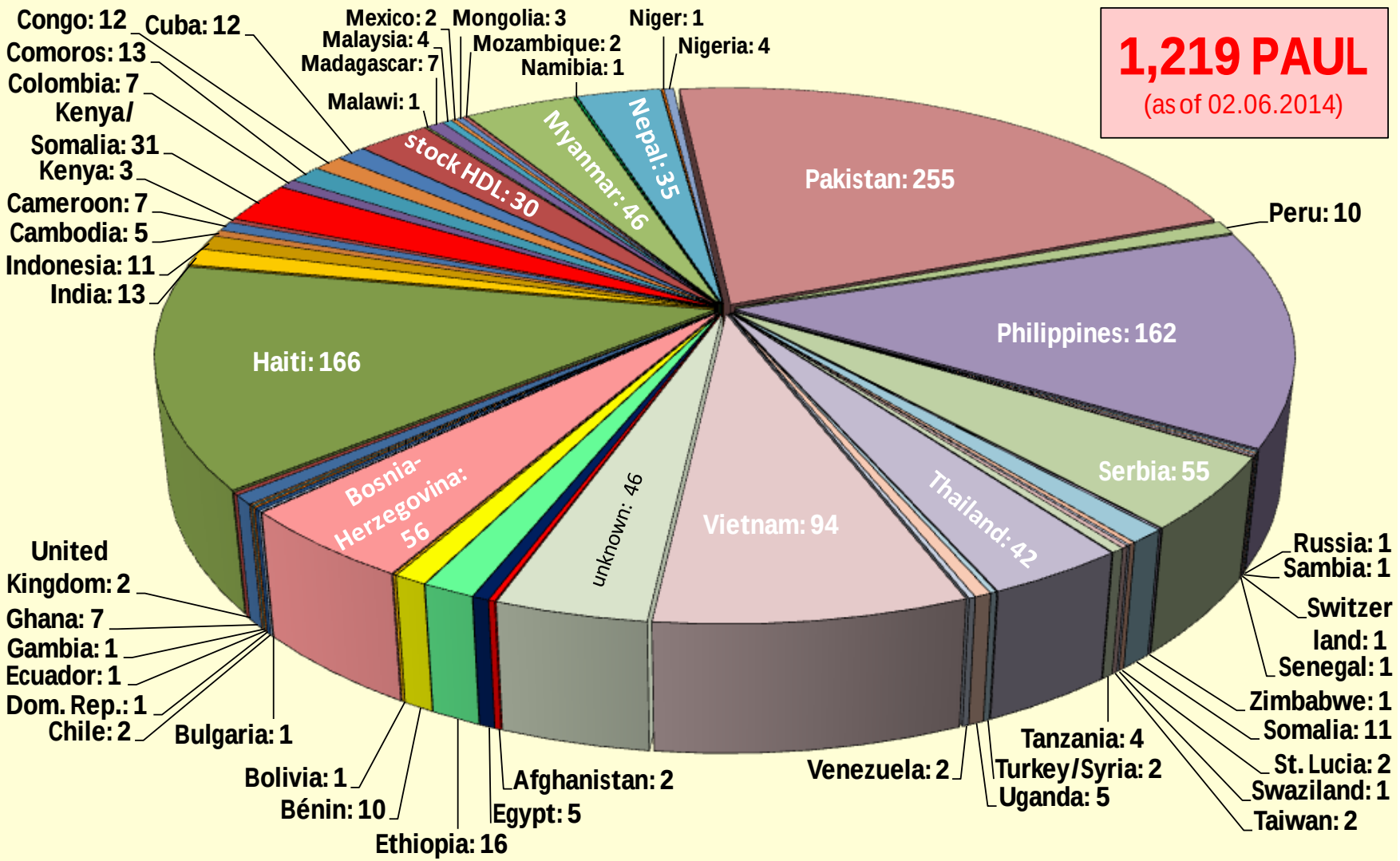
Ü See the complete operation manual!



gefördert durch
DBU
Deutsche Bundesstiftung Umwelt
www.dbu.de

Portable
Aqua
Unit for
L ifesaving

ULPUF+dead end systems **PAUL** in use today



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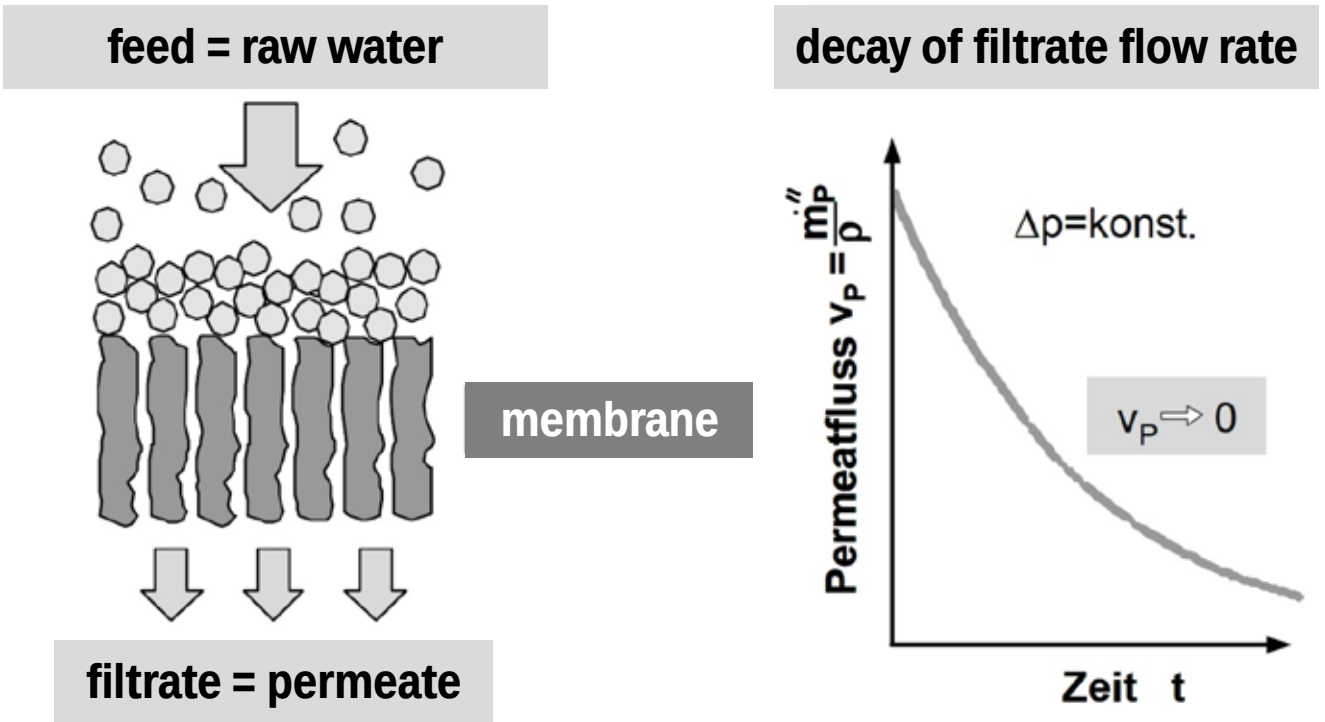
As in this scenario neither backflush nor cross flow is possible: what about dead end filtration? - the Q&A section -

- Ü dead end filtration
- Ü ultra low pressure: 0.00 to 0.08 bar (0.04 typical)
- Ü 9.5 m² membrane surface area
- Ü nominal flux 5 LMH, nominal yield 1,200 L/d
- Ü flat sheet vertically mounted

- dead end filtration
- according to literature, the permeate flow will come to zero (with TMP between 0.3 and 10 bar)



Melin/Rautenbach: Membranverfahren. 3rd edition 2007. ISBN 978-3-540-34327-1 Springer Berlin Heidelberg New York

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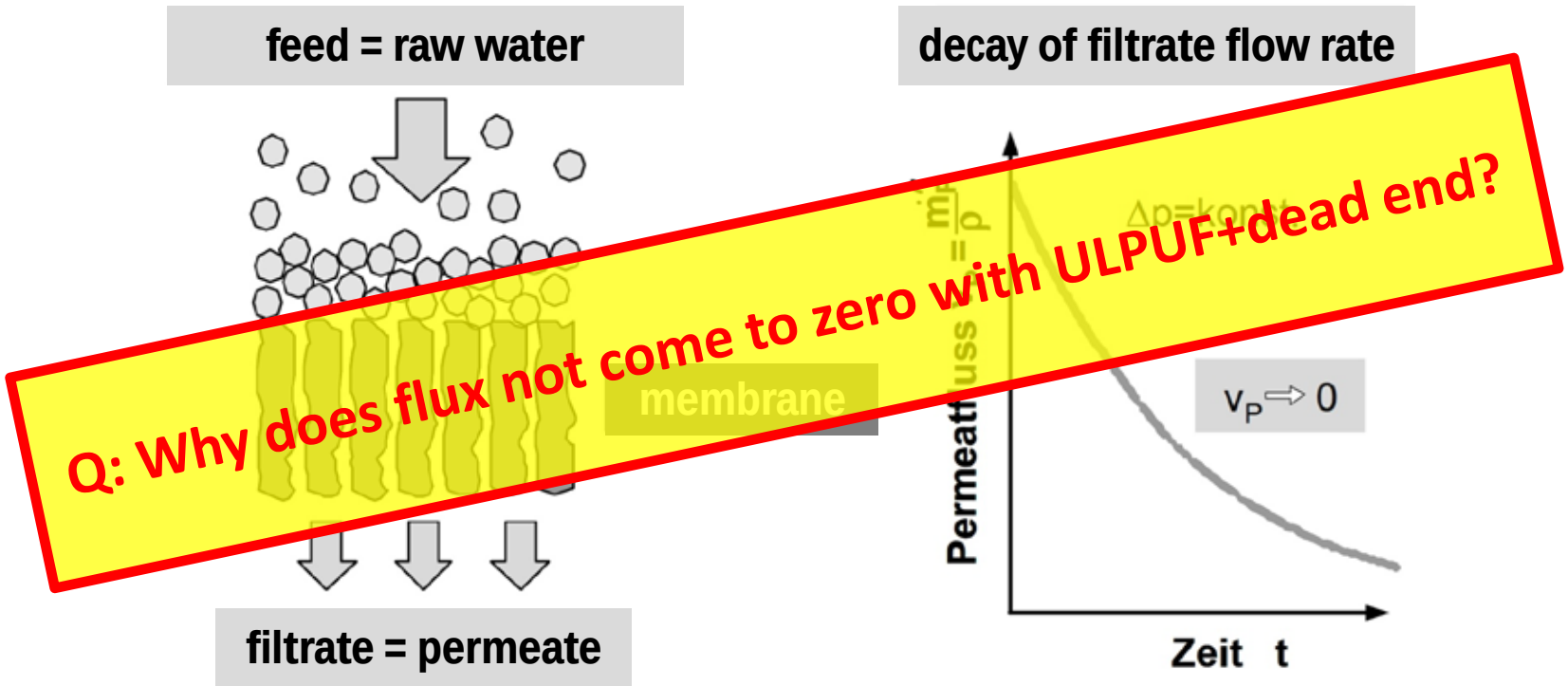

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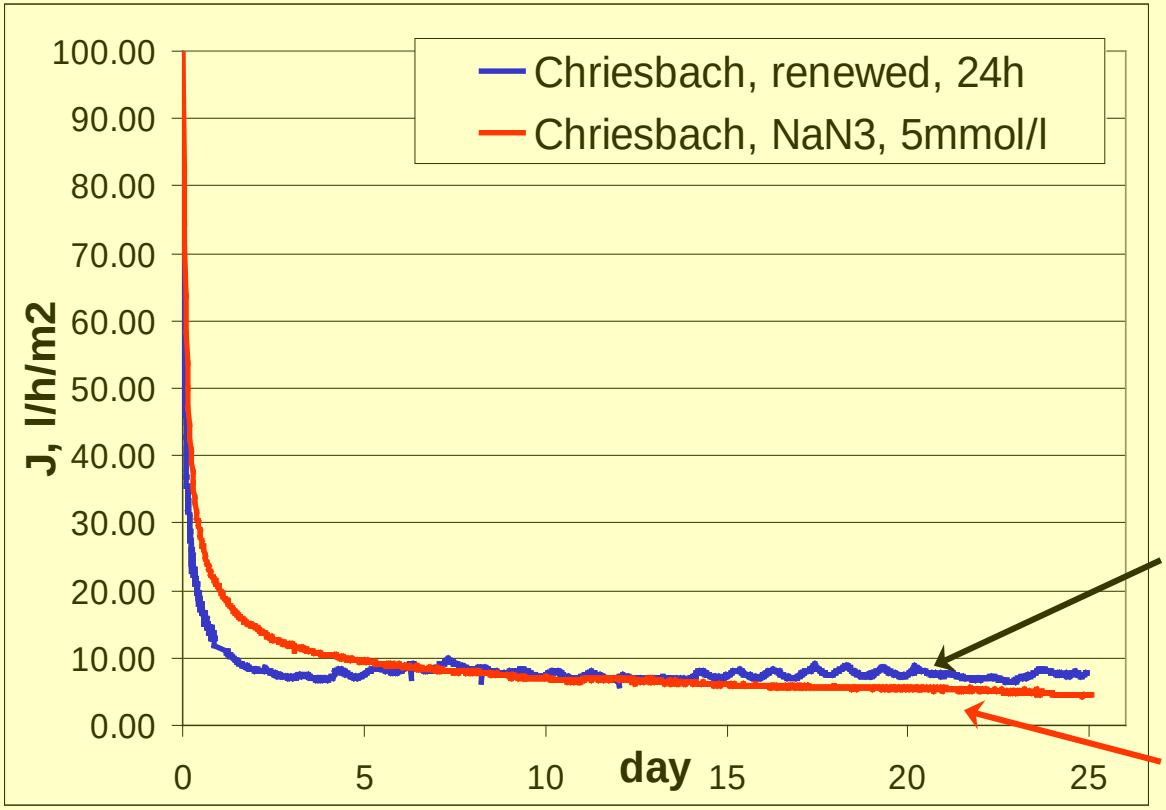
1. Bacterial activity keeps up cake layer permeability



Chriesbach River water:
DOC 3.1 - 4.6 mgC/l
Turbidity: 1.5 - 24 NTU
With and without 5M NaN3

Daily fluctuation but on average stable flux

Slow but steady flux reduction

From Presentation Peter/Pronk (EAWAG) 2005, Techneau workshop, Berlin

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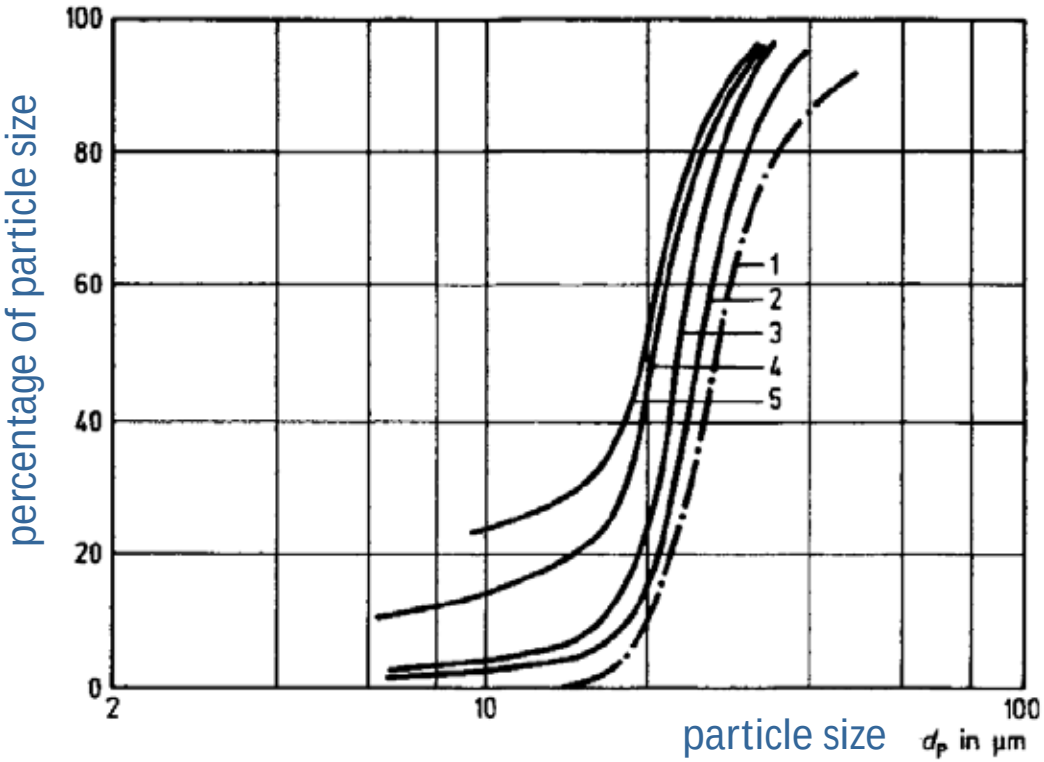
2. dead end filtration – no sizing effect

- Ü acc. to Ripperger, high velocities (= forces) along the membrane surface have a sizing effect, leaving higher percentages of small particles on the membrane: increased likeliness of pore clogging
- Ü in the ULPUF, vertical force is much lower than with cross flow filtration !



1 no crossflow (original particle distribution)
2 ... 5 increasing crossflow velocity from 0.3 m/s to 1.5 m/s

Rippberger ,S.(1993): Berechnungsansätze zur Crossflow-Filtration. Chem-Ing-Tech. 65, Nr 5, 533-540

3. Low TMP

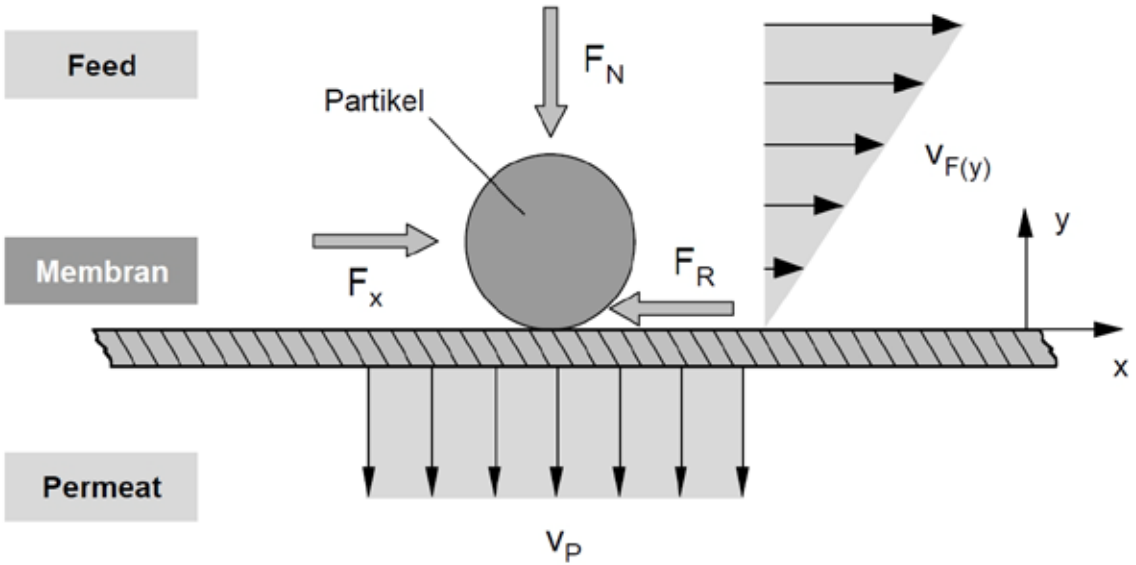
- Ü The higher the TMP as the driving force for small particles to be dragged into the pores, the lower the occurrence of pore blocking
- Ü With ultra low TMP, the small particles presumably cannot even pass the **cake layer**

.. oh, talking about cake layer ...

- Ü dead end filtration
- Ü dead end filtration is only recommended with very low suspended solids content – as can be found in surface waters (in general and during emergencies)
- Ü cake layer has to be removed somehow – but if simple operation is essential, this cannot be done by **backflush**

Q: how to remove the cake layer?

models of cake layer with cross flow ...



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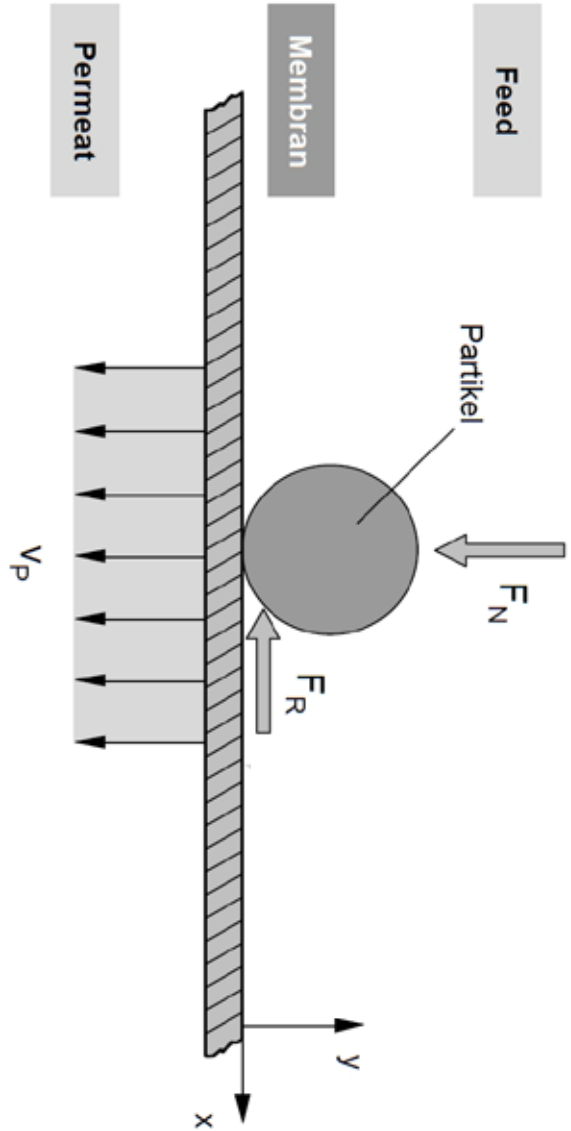
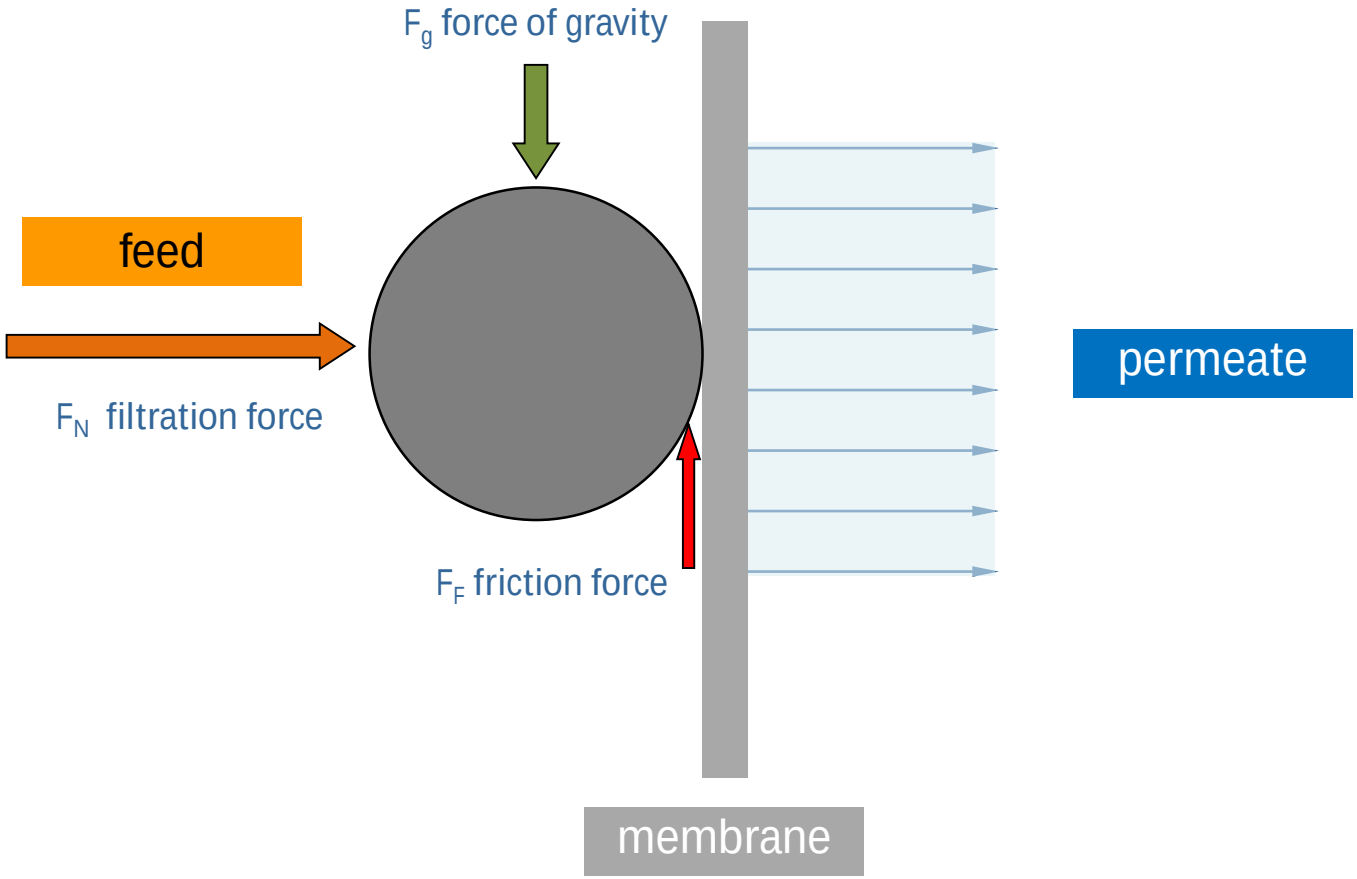
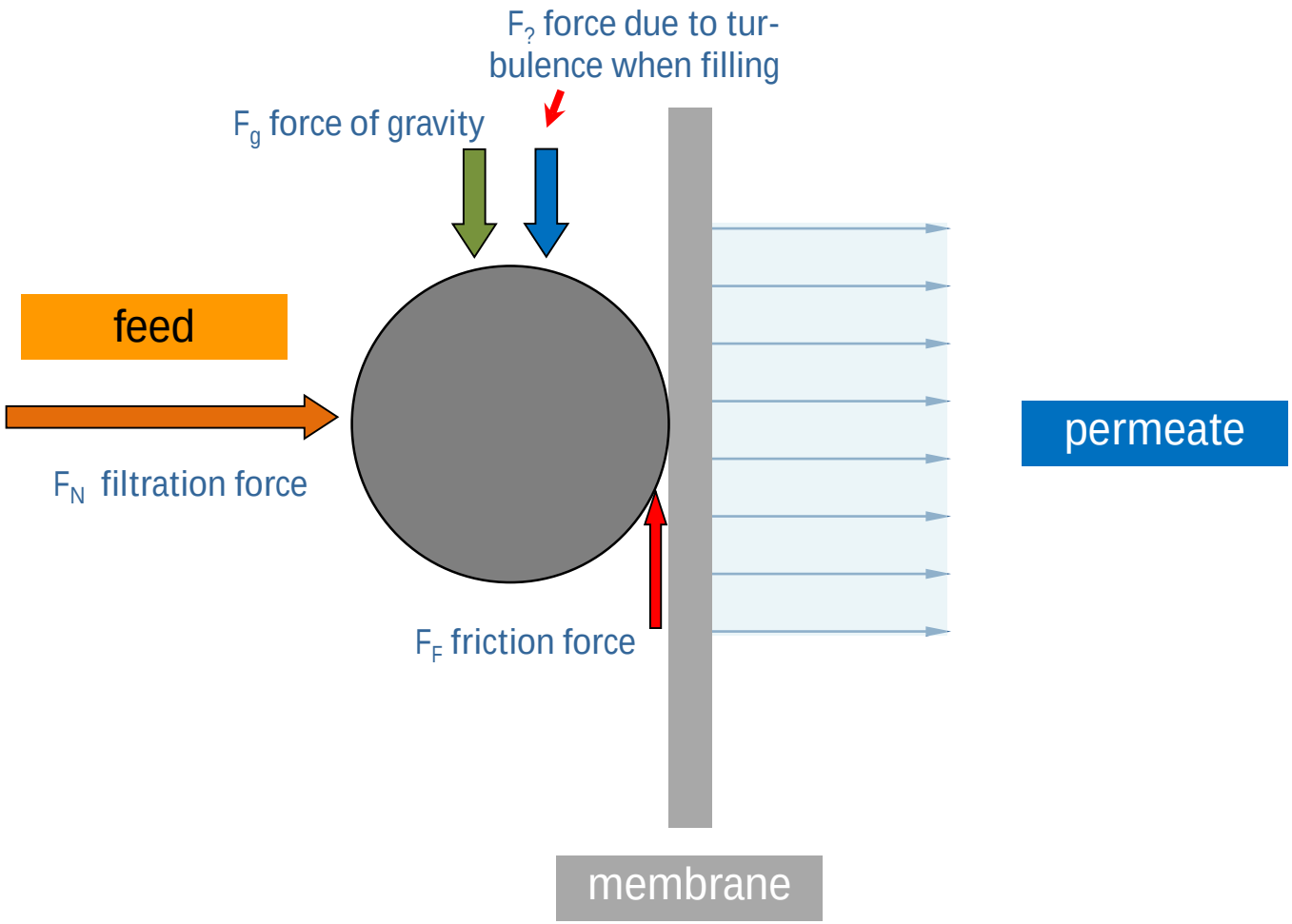


Ü flat sheet vertically mounted

Ü forces at a cake layer particle during filtration



Ü forces at a cake layer particle during filtration and filling



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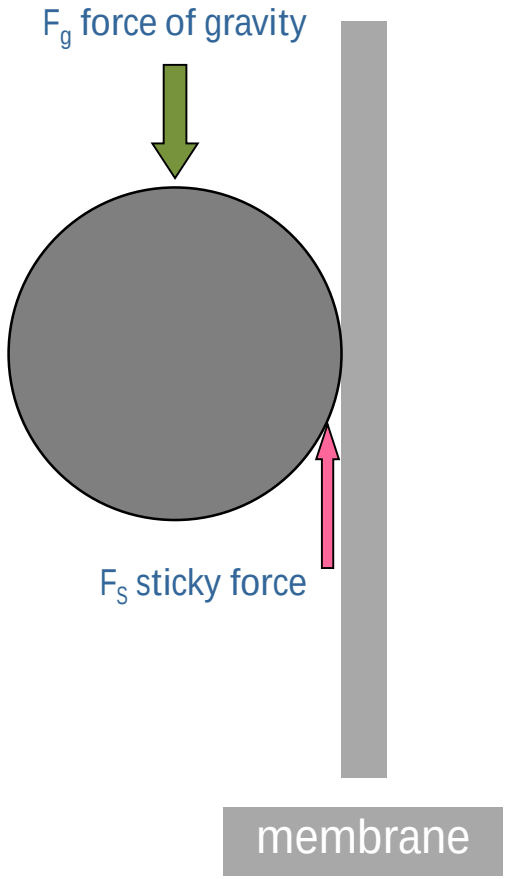
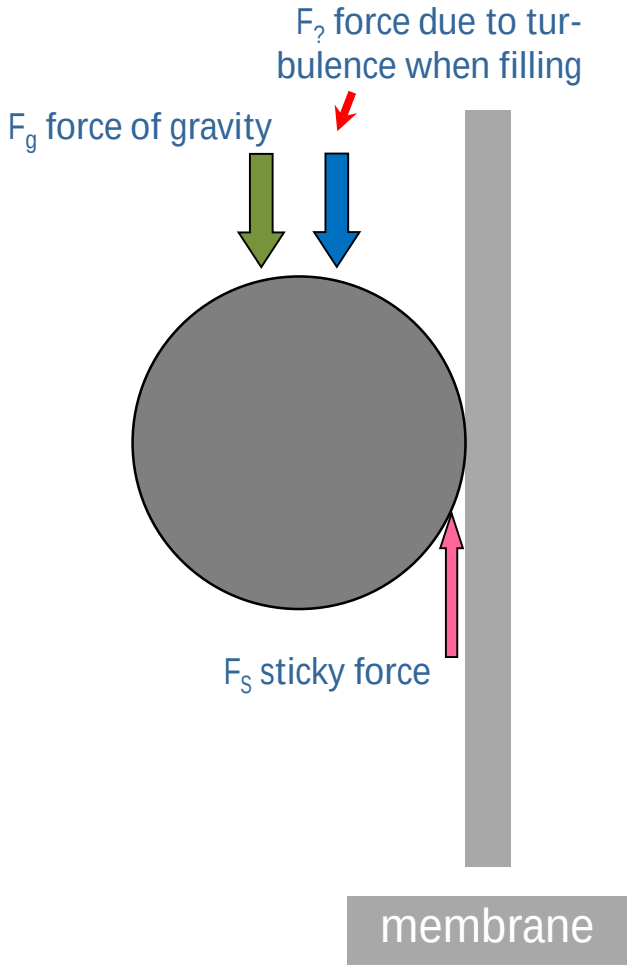
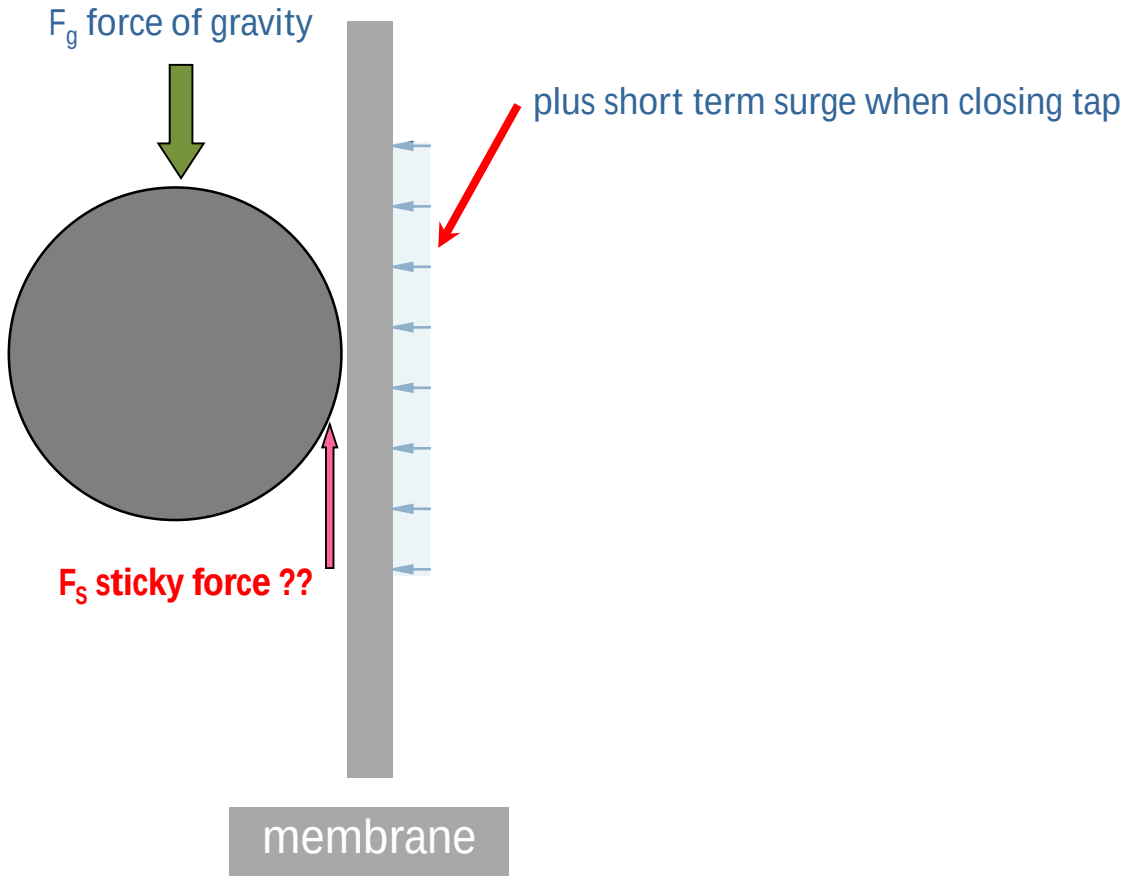
Ü forces at a cake layer particle during filtration pause



Ü forces at a cake layer particle during filtration pause and filling



Ü forces at a cake layer particle during tap closing



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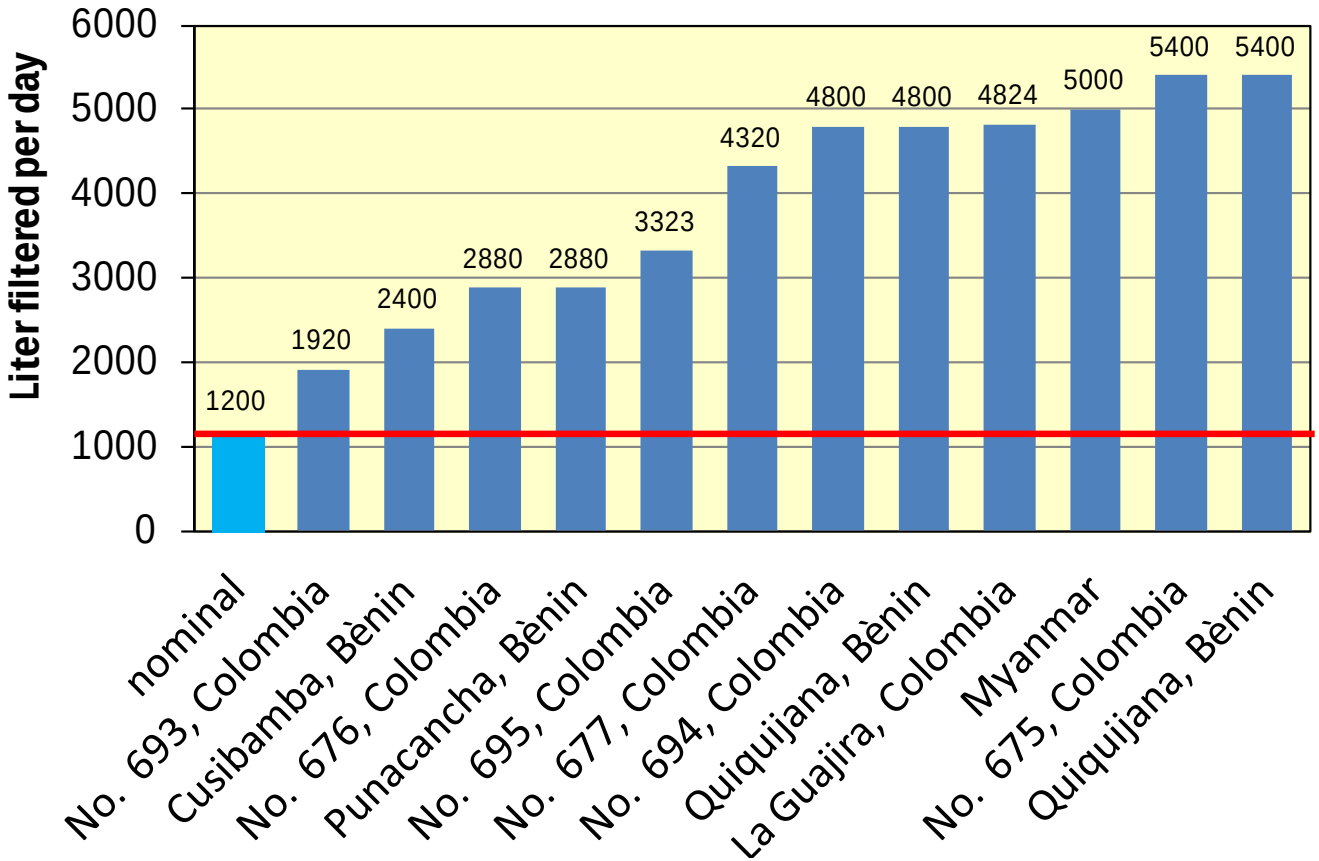
- Ü **All** measurements of PAULs **onsite** (Columbia, Benin, Myanmar etc.) indicate higher amounts:



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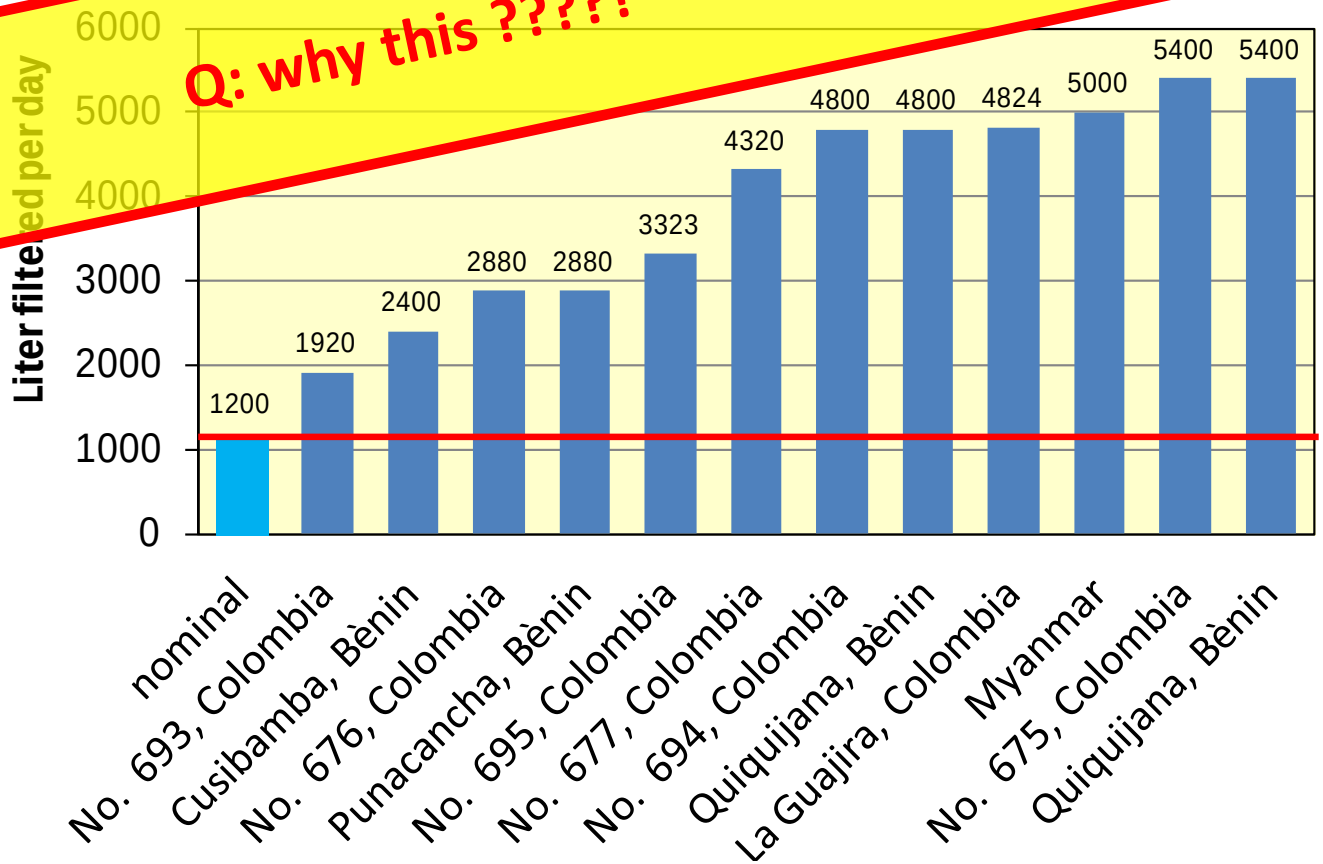
Q: why this ?????



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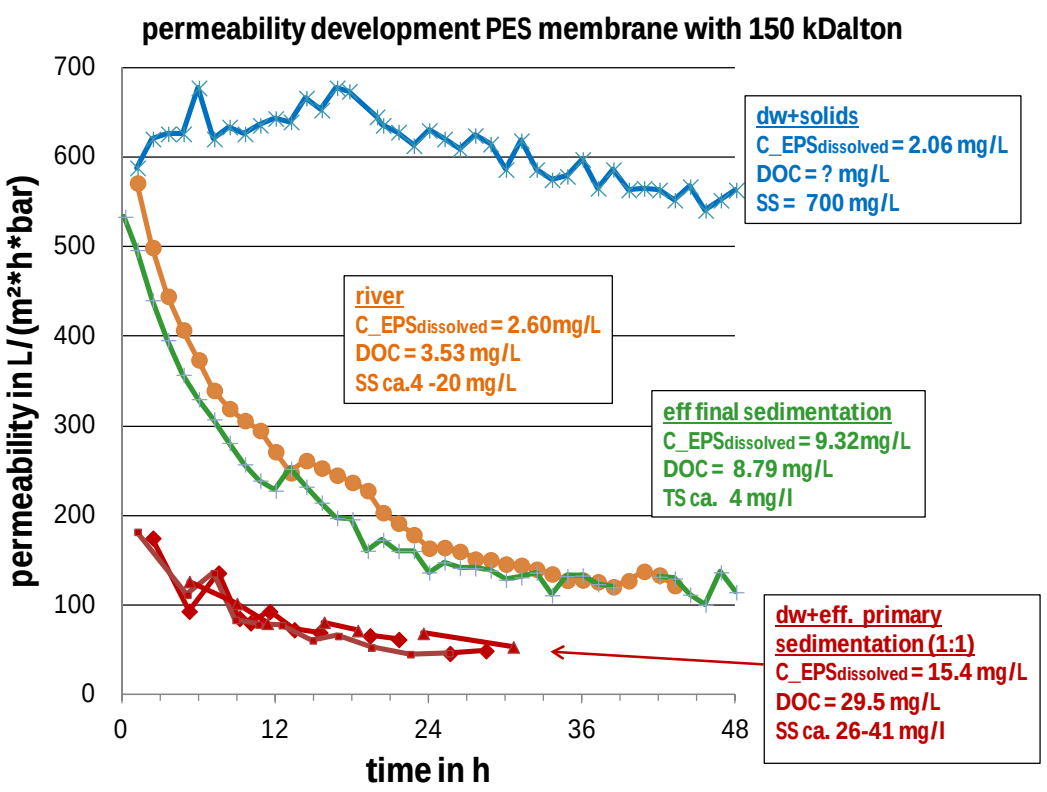
capacity of **PAUL:** influence of EPS & temperature

- Ü in cases of emergency and in rural areas (well water or surface water), usually low EPS concentrations are observed
- Ü also, temperatures are higher than in Kassel



Exler, H.; Telgmann, U.; Frechen, F.-B (2013): Einfluss gelöster organischer Verbindungen (EPS) auf die hydraulische Leistungsfähigkeit von Membranen gwf - Wasser|Abwasser, June 2013

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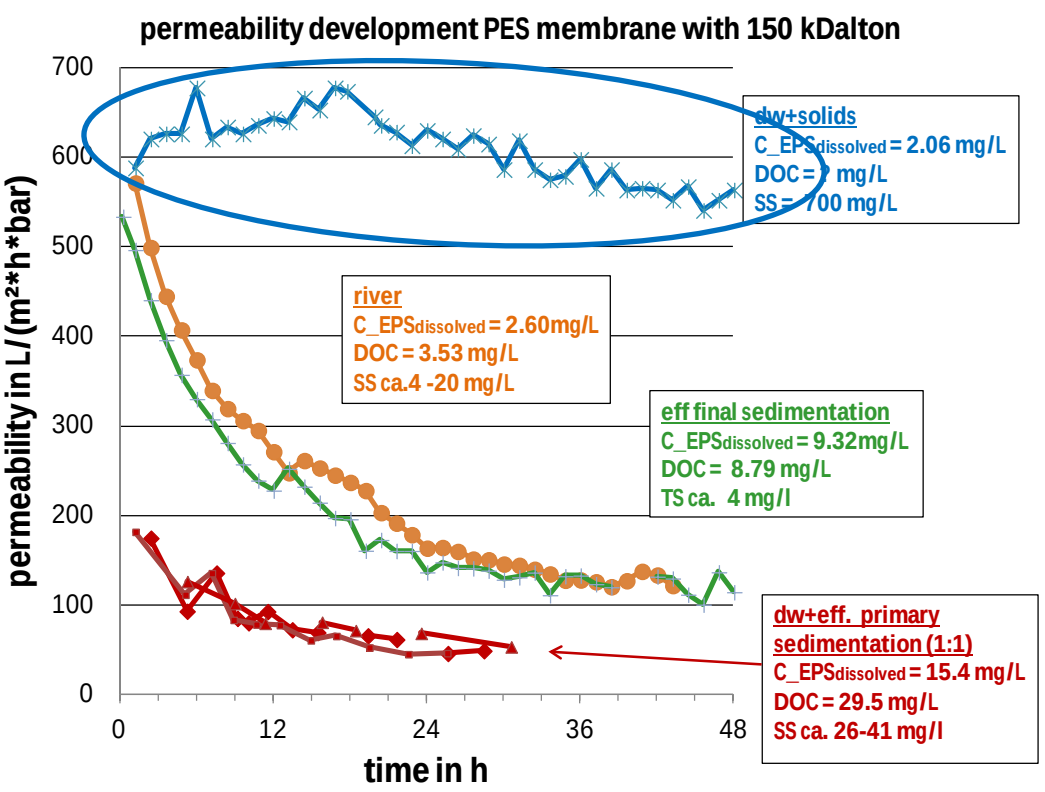

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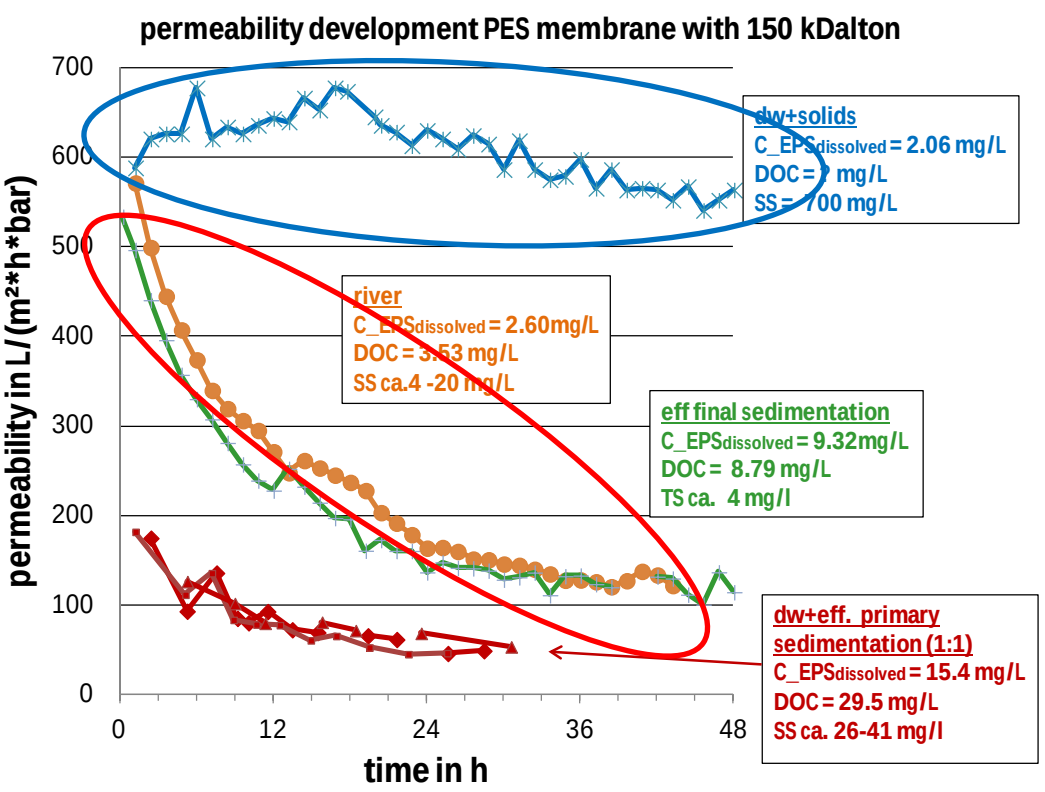

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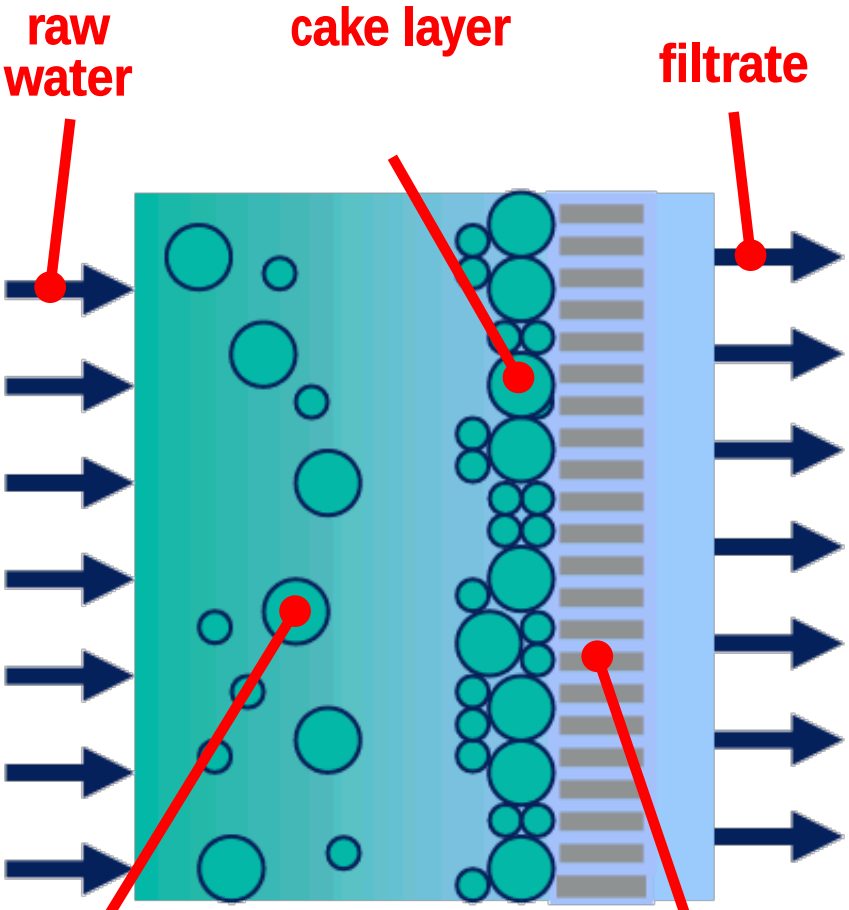
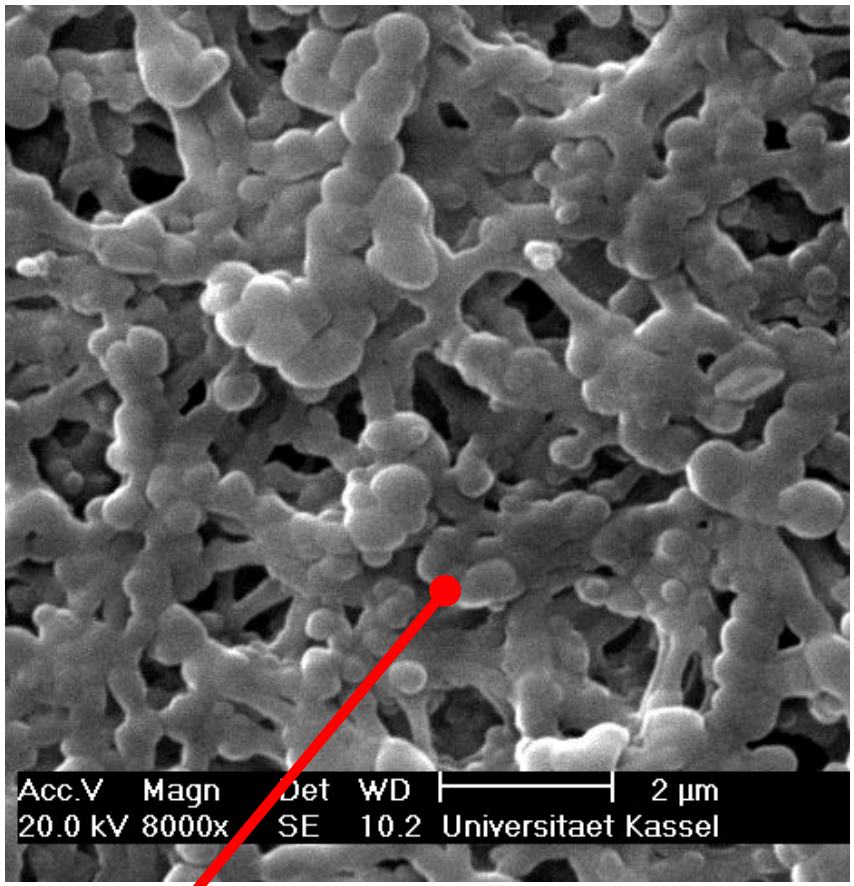
conclusion: filtration is mostly done by ???





typical pore width 20 to 100 nm (0.020 to 0.100 µm)

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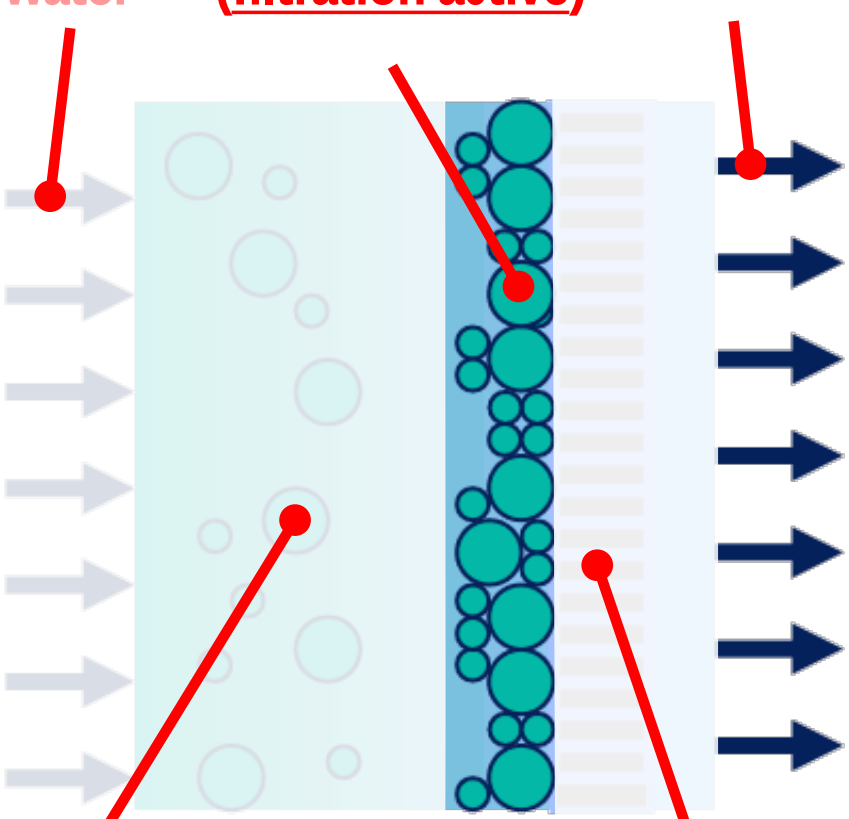
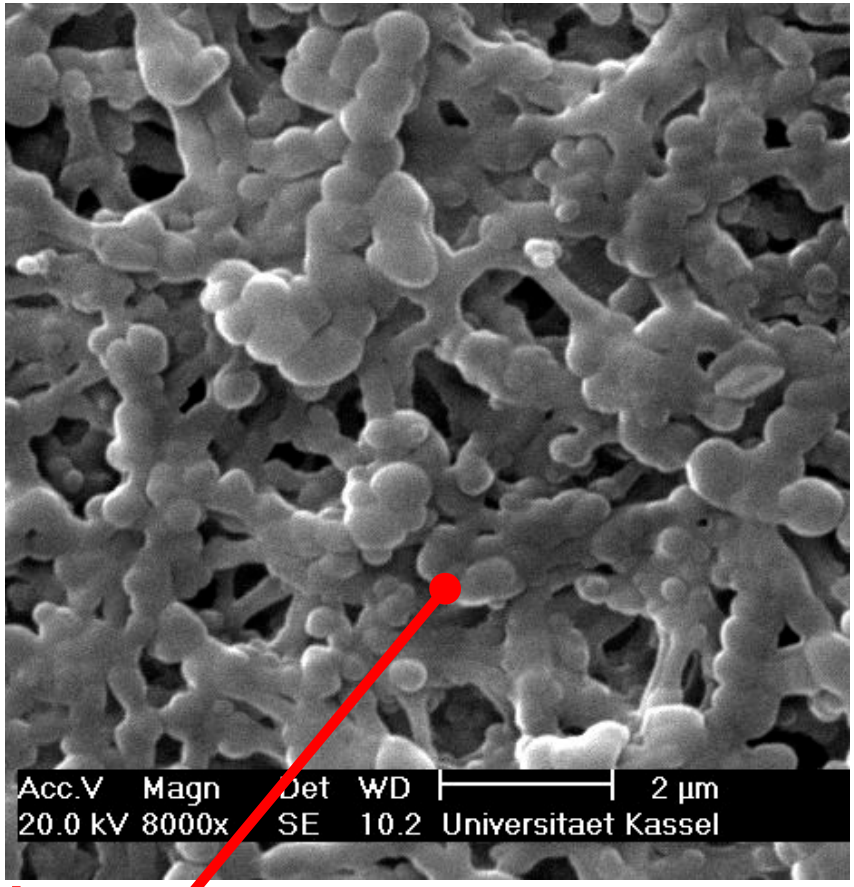
conclusion: filtration is mostly done by the **cake layer**





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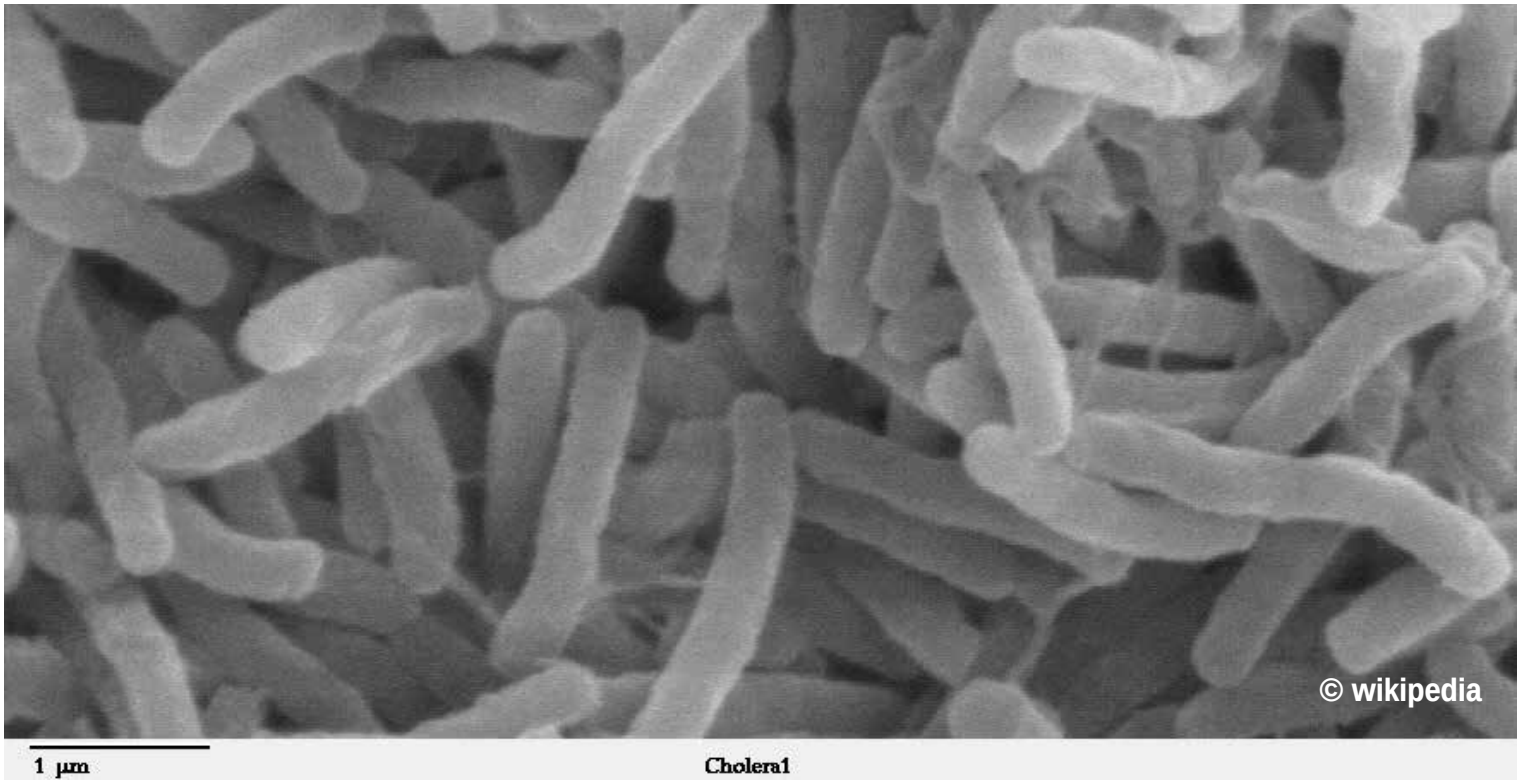
removal of bacteria, example cholera



cholera bacteria

diameter 300 to 500 nm, length 2 000 nm (2 µm)

membrane

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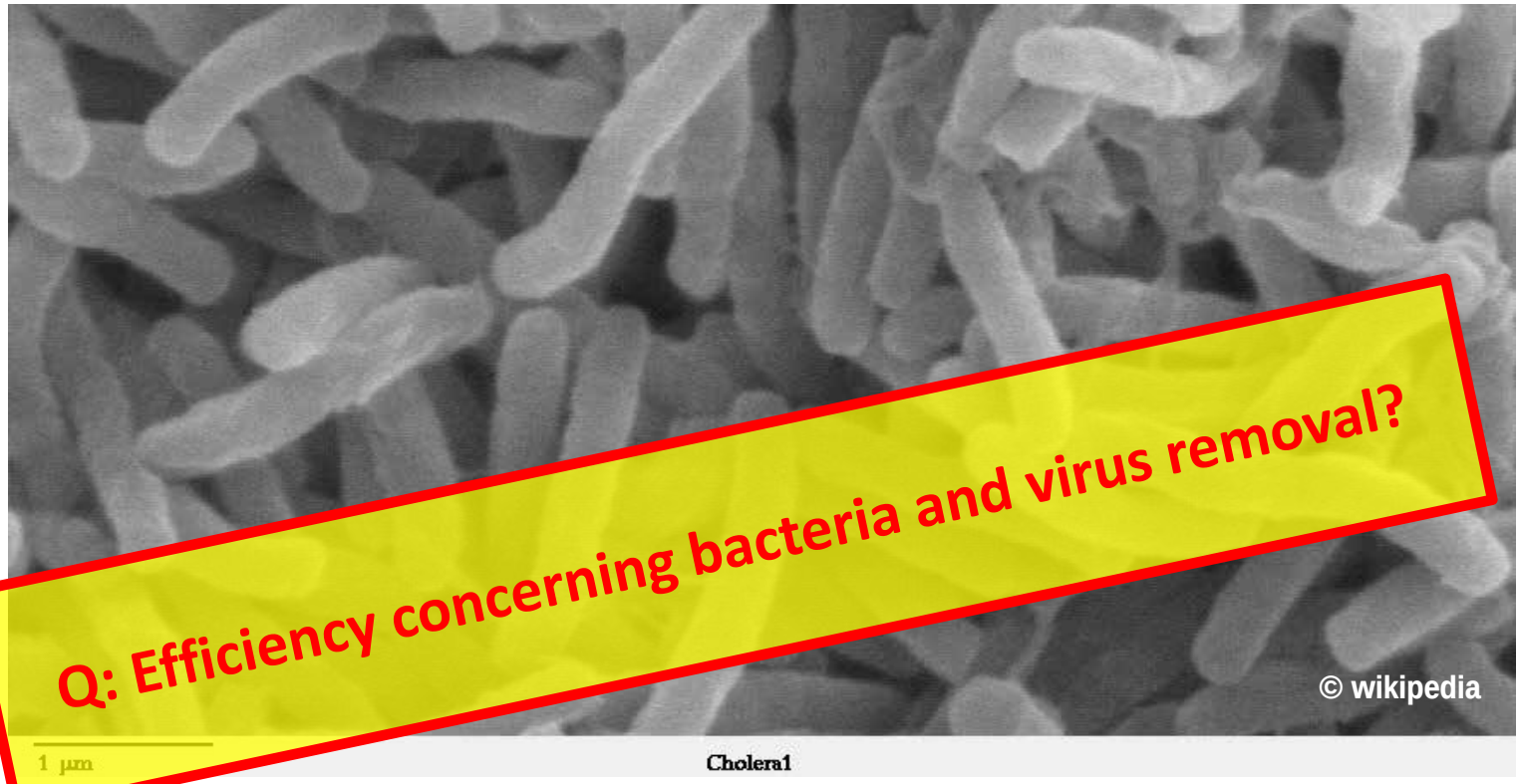

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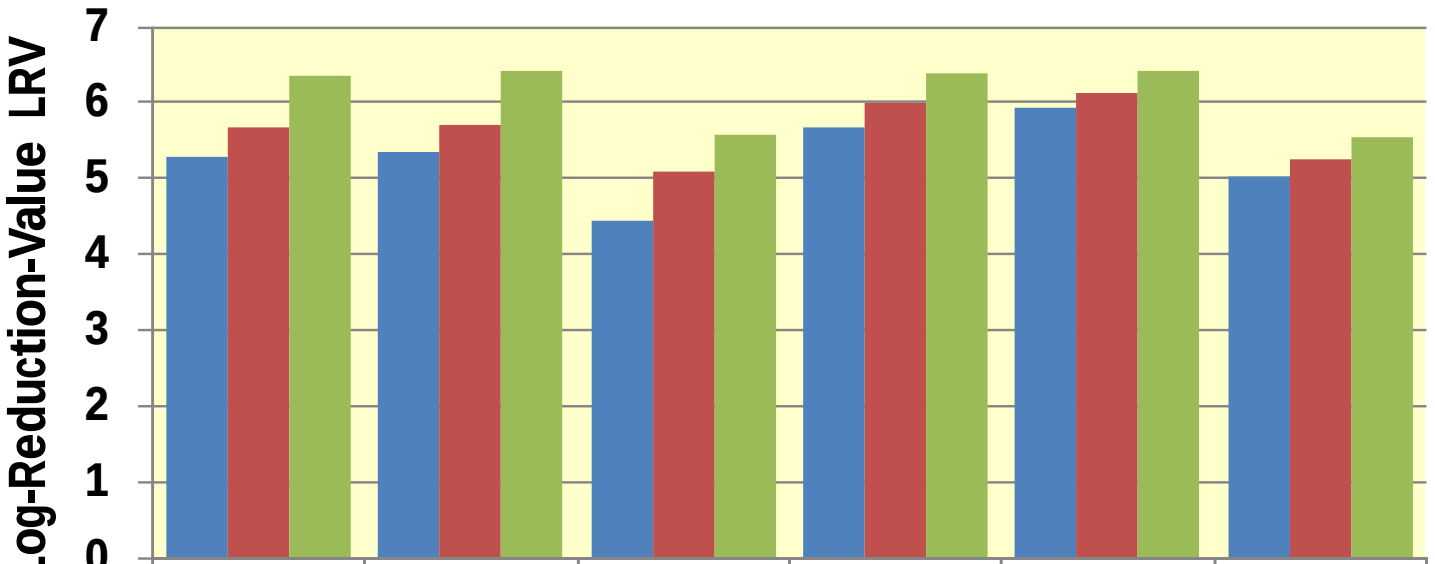
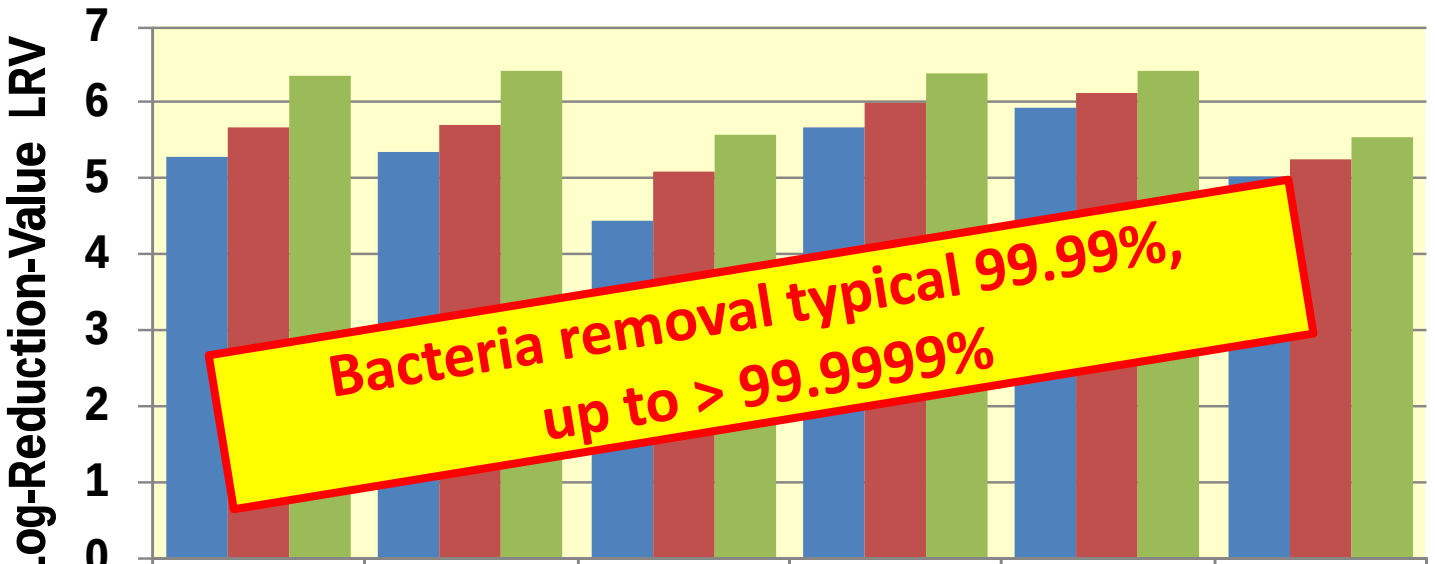


	Fresenius e.coli ISO 9308-1 PAUL A	Fresenius coliforme ISO 9308-1 PAUL A	Fresenius I.E. ISO 7899-2 PAUL A	Fresenius e.coli ISO 9308-1 PAUL B	Fresenius coliforme ISO 9308-1 PAUL B	Fresenius I.E. ISO 7899-2 PAUL B
min	5,301	5,368	4,444	5,672	5,929	5,041
avg	5,689	5,704	5,092	6,013	6,144	5,245
max	6,362	6,415	5,568	6,380	6,431	5,544

analyzed by Institut Fresenius, Göttingen

bacteria removal



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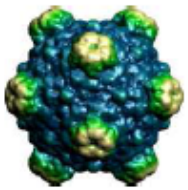
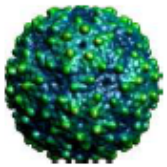
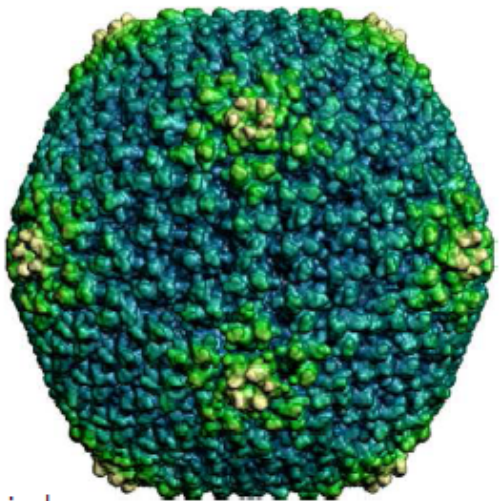
analyzed by Institut Fresenius, Göttingen

- added virusses
  - ΦX174
  - MS2



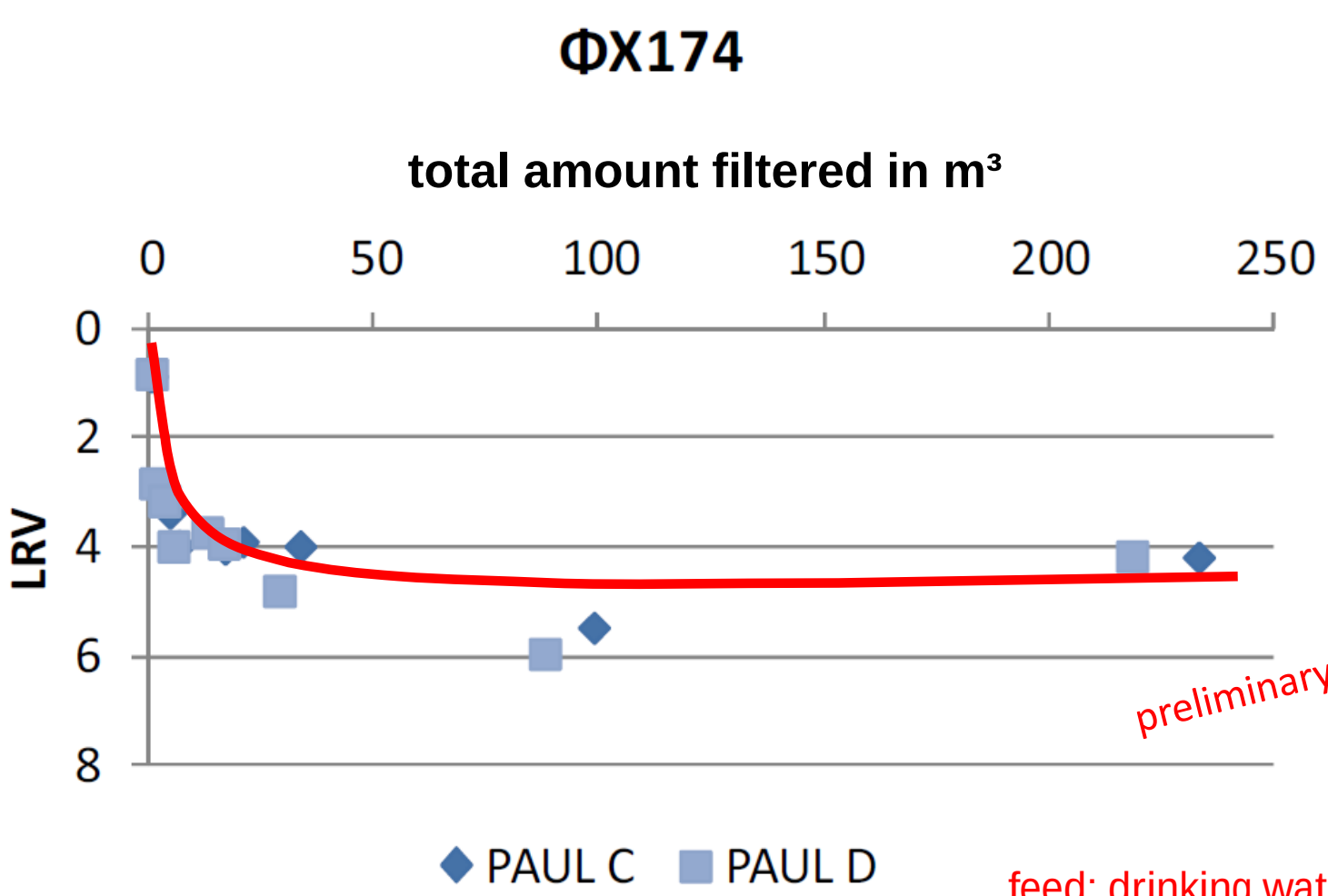


- human adenovirusses



Quelle:
VIPERdb2: an enhanced and web API enabled relational database for structural virology.
Mauricio Carrillo-Tripp, Craig M. Shepherd, Ian A. Borelli, Sangita Venkataraman, Gabriel Lander, Padmaja Natarajan, John E. Johnson, Charles L. Brooks, III and Vijay S. Reddy
Nucleic Acid Research 37, D436-D442 (2009); doi: 10.1093/nar/gkn840

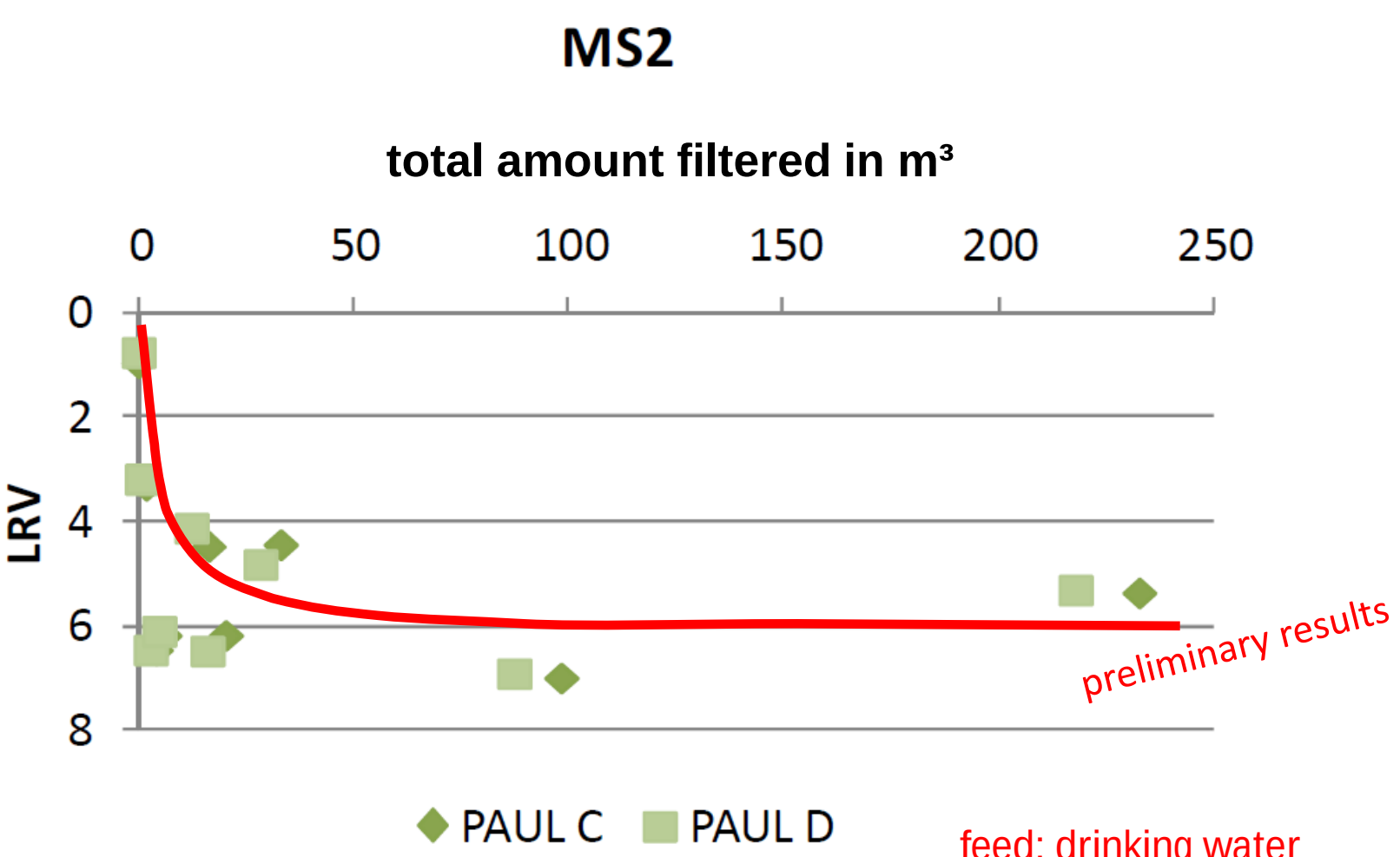
virus removal (Federal Environment Agency UBA)



feed: drinking water

analyzed by Federal Environment Agency, Dessau/Roßlau

virus removal (Federal Environment Agency UBA)



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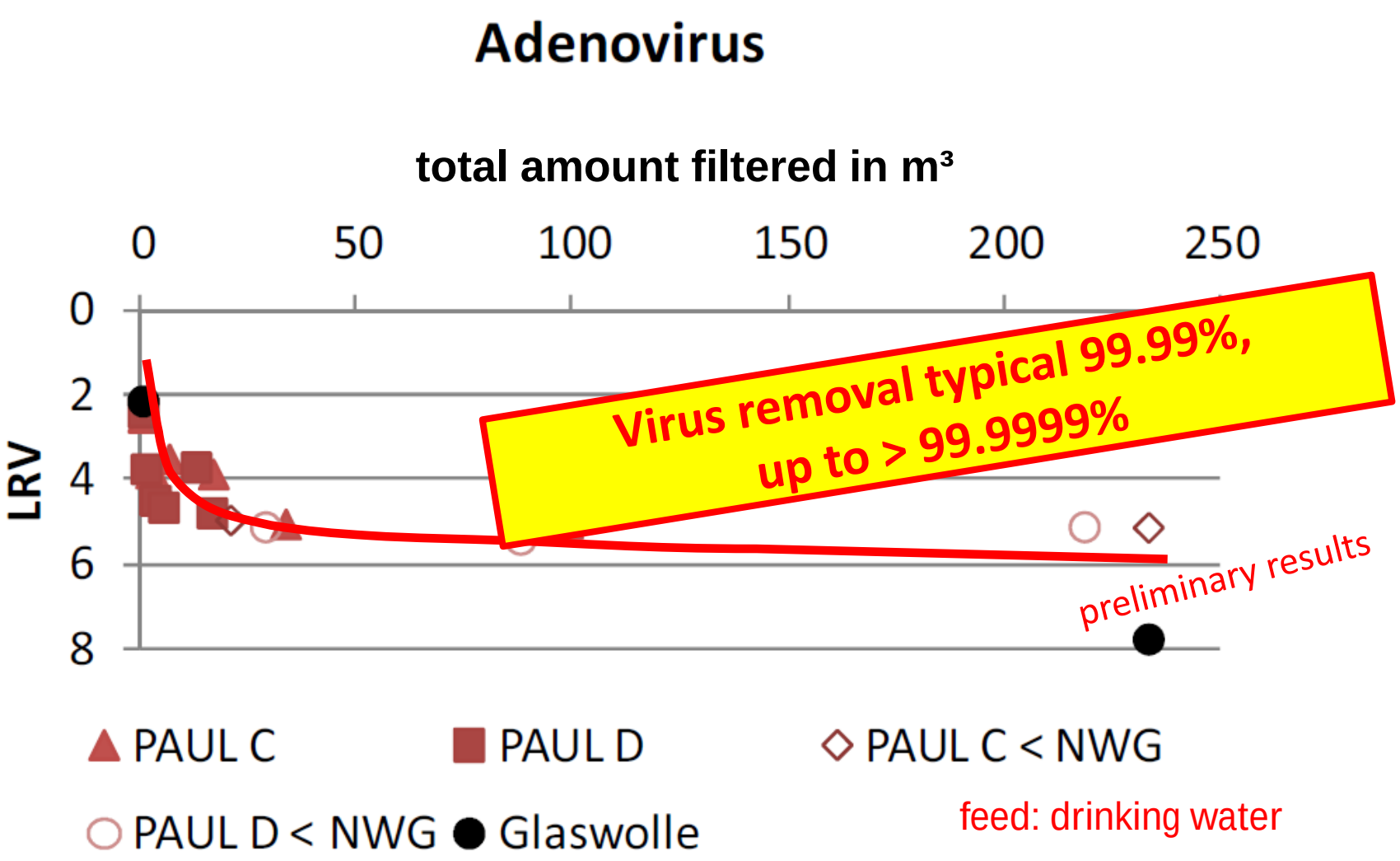

analyzed by Federal Environment Agency, Dessau/Roßlau

conclusions

Ü **dead end** filtration in an **ULPUF** process:

1. ULPUF+dead end achieves **LRV from 3 up to more than 6** for **bacteria** as well as for **viruses**
2. the membrane more or less only serves as a support for the **filtrating cake layer** → this is also exemplified by the **high LRV for viruses**
3. no cross flow, thus no sizing effect of the cake layer → low risk of **pore blocking**
4. TMP is ultra low, this means driving force of small particles through the cake layer into the pores is very low → low risk of **pore blocking**
5. if EPS occur, they will be transported down to the bottom volume and not be recycled to the membrane surface
6. structure of the cake layer and **bacterial activity** keep up the cake layer's permeability

Low invest, small area: high maintenance & replacement costs ⟷ **high invest, large area: low maintenance & no replacement costs**

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ultra low TMP: "accelerating by throttling"

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Ü is dead end filtration dead?

NO !

Ü maybe it's just sleeping .....

3-6 December 2014 IWA Membrane Regional Conference in Ho Chi Minh City

Nov. 2015 IWA Membrane Biennial Conference in Abu Dhabi

Cheers !