8th IWA Membrane Technology Conference & Exhibition for Water and Wastewater Treatment and Reuse

5th – 9th September 2017, Singapore

Membranes and the Sustainable Development Goals

AQUA AWARD 2017
AQUANET
BERLIN BRANDENBURG

GreenTec Awards
WINNER 2016
Water & Sewage

Singapore, 6th September 2017

modified 12th June 2018

Franz-Bernd Frechen, IWA Fellow

Chair, IWA Specialist Group „Membrane Technology“

Chair, DWA Committee on „Membrane Bioreactors“

gefördert durch
DBU
Deutsche Bundesstiftung Umwelt
www.dbu.de

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

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Deutschland Land der Ideen Ausgewählter Ort 2011
German Water Partnership
dex
UNIKASSEL VERSITÄT

SUSTAINABLE DEVELOPMENT GOALS

How can membranes contribute??

Sanitation

Clean water

Quelle: http://www.un.org/sustainabledevelopment/sustainable-development-goals/

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- 2.6 billion people have gained access to **improved drinking water sources** since 1990

This means: 287,000 people every day since 1990 !

Quelle: http://www.un.org/sustainabledevelopment/sustainable-development-goals/

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- 2.6 billion people have gained access to **improved drinking water sources** since 1990, but **663 million people are still without – 80% of them live in rural areas**
- At least **1.8 billion people globally use a source of drinking water that is fecally contaminated**
- Between 1990 and 2015, the proportion of the global population using an improved drinking water source has increased from 76 per cent to 91 per cent
- But water scarcity affects more than 40 per cent of the global population and is projected to rise. Over 1.7 billion people are currently living in river basins where water use exceeds recharge
- **2.4 billion people lack access to basic sanitation services, such as toilets or latrines**
- More than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal
- **Each day, nearly 1,000 children die due to preventable water and sanitation-related diarrhoeal diseases**
- Hydropower is the most important and widely-used renewable source of energy and as of 2011, represented 16 per cent of total electricity production worldwide
- Approximately 70 per cent of all water abstracted from rivers, lakes and aquifers is used for irrigation
- Floods and other water-related disasters account for 70 per cent of all deaths related to natural disasters

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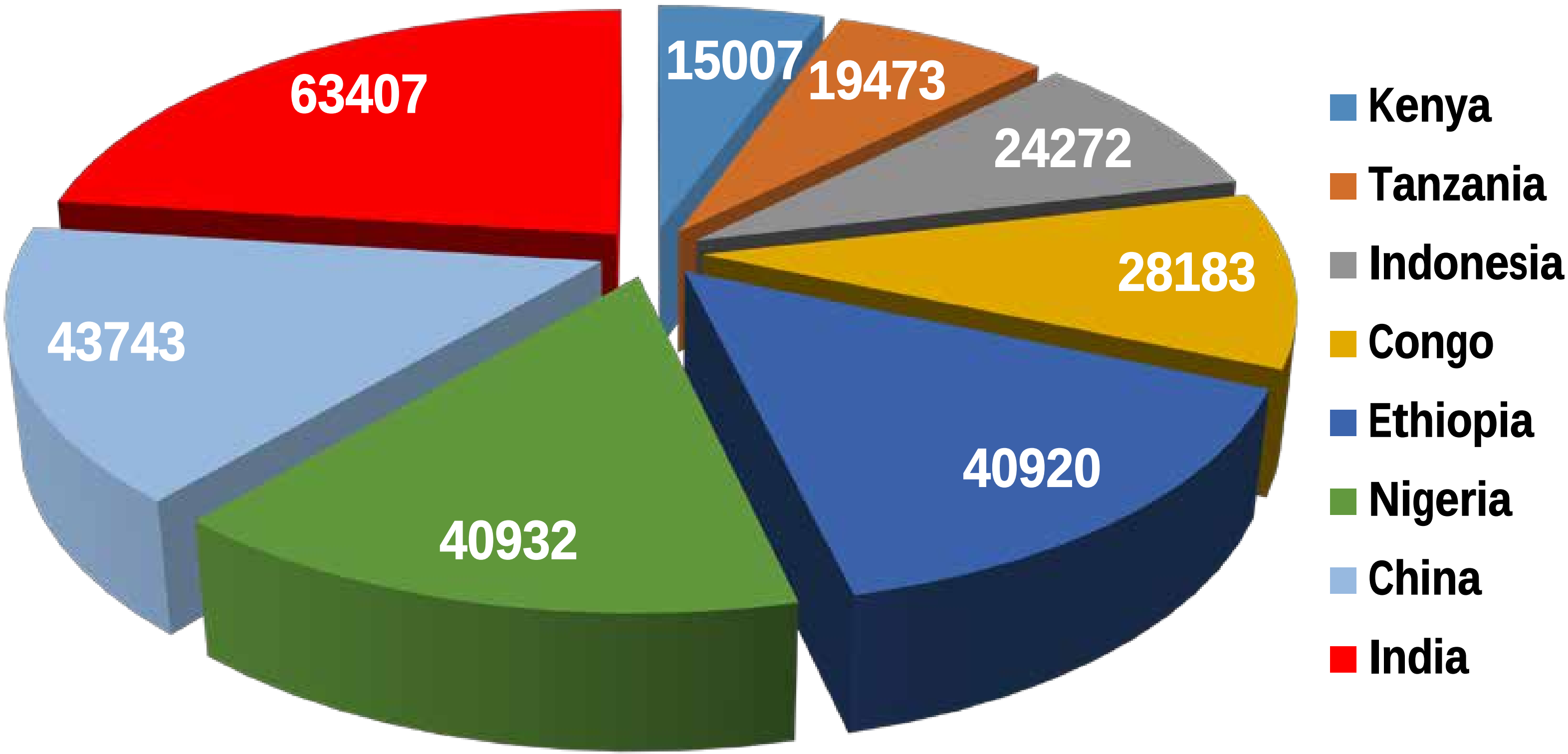
SDGoal 6 demands:

By 2030, achieve universal and equitable access to safe and affordable drinking water for all

This means: 340,000 people every day until 2030 !

Quelle: http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Countries with more than 15 mio. people in rural areas w/o access to safe water [in 1,000] - Total: 276 Mio.



Quelle: http://www.wssinfo.org/data-estimates/tables/

how it all began

- Ü Membranes are able to retain **bacteria**. So why not use membranes to retain bacteria and pathogens, the <u>most serious concern in disasters</u>?
- Ü In disasters, **cities** are aided with large mobile waterworks
- Ü **Rural areas**, however, in most cases only receive chlorine tablets or are even fobbed off totally.
- Ü The original task of our research, starting in 2001, was to create a **small** unit that provides **<u>potable water</u>** in **<u>emergencies</u>**, characterized by
  - Ä No **energy** needed
  - Ä No **chemicals** needed
  - Ä Simple & robust
  - Ä No or nearly no **maintenance** needed
  - Ä Operational even for **illiterate**s
  - Ä Lightweight and **easily transportable**, even hands-free as a backpack
  - Ä Designed to help in **emergencies** and **disasters**
- Ü The result was the waterbackpack **“PAUL”**, a **research project** mainly financed by the **German Federal Environmental Foundation**

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Disasters: e.g. Pakistan, flooding, July 2010

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WaterBackpack “**PAUL**” designed by DESEE:

Ü **starting 2001,** at DESEE we designed the **WaterBackpack** “**PAUL**”, a small **membrane ultrafiltration** (**UF**) unit

Ü membr. area 9.5 m², 150 kDa

Ü **1,200 L/d (1.2 tons) for 400 people in emergency and 60 people as permanent supply**

Ü weight: **20 kg**, 0.4 x 0.4 x1.1 m

Ü No **chemicals**, no **electricity**, operates with **gravity**

Ü can be operated even by illiterates

Ü no maintenance during **emergencies**

Ü 6 or 12 on one Euro-Palette

Ü ***lifetime 10 years*** ð ***permanent supply***

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operation principles **PAUL**

- Ü dead end filtration
- Ü **ultra low pressure: 0.00 to 0.08 bar (0.04 typical)**
- Ü 9.5 m² membrane surface area, **lifetime 10+ years**
- Ü nominal flux 5 LMH, nominal yield 1,200 L/d, measurements of units in practical operation range from 2 to 6 m³/d
- Ü We called it the **U**ltra **L**ow **P**ressure **UF** process (**ULP-UF** process)



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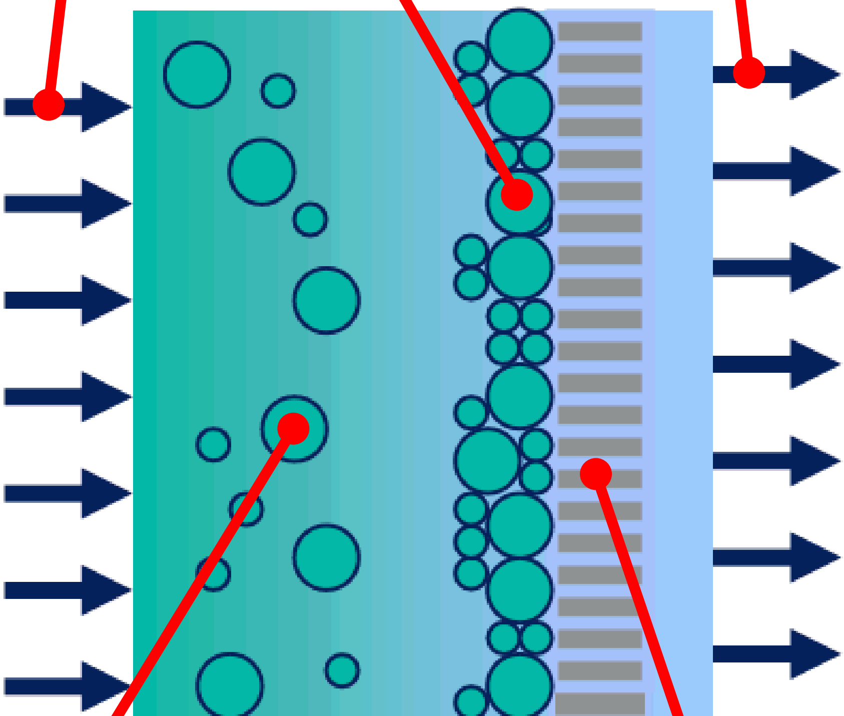
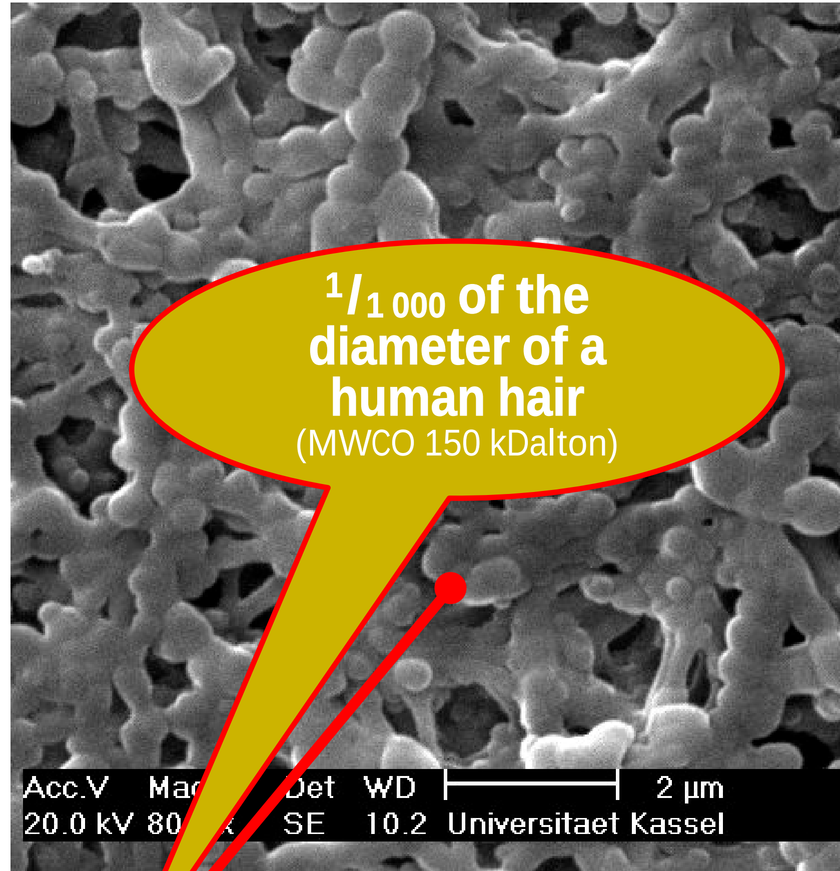
filtration is mostly done by the **cake layer**

raw water

cake layer (filtration active)

filtrate





Solids (organic, anorganic, bacteria, pathogens, ...)

membrane

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

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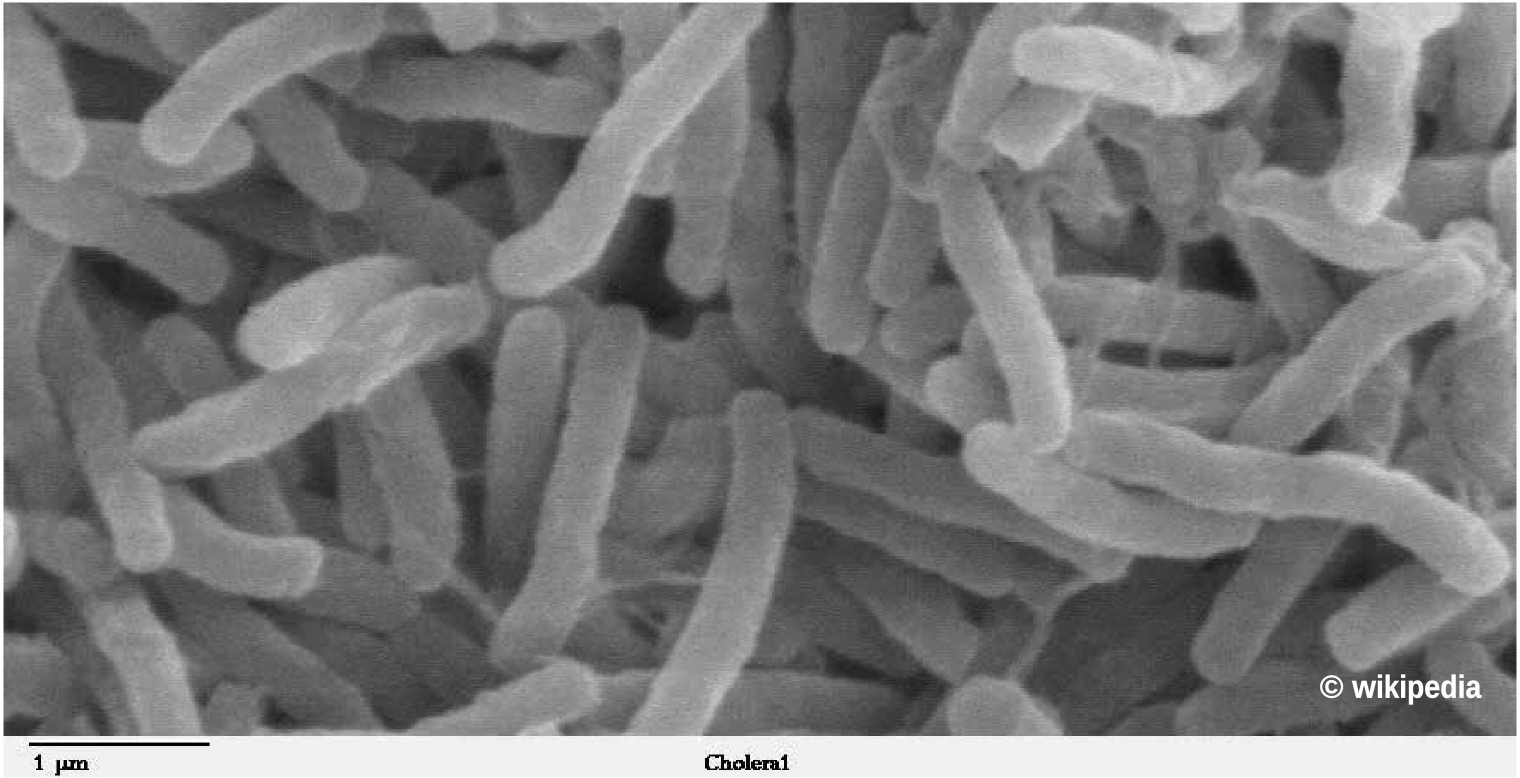
removal of bacteria, example cholera



cholera bacteria

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

membrane

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

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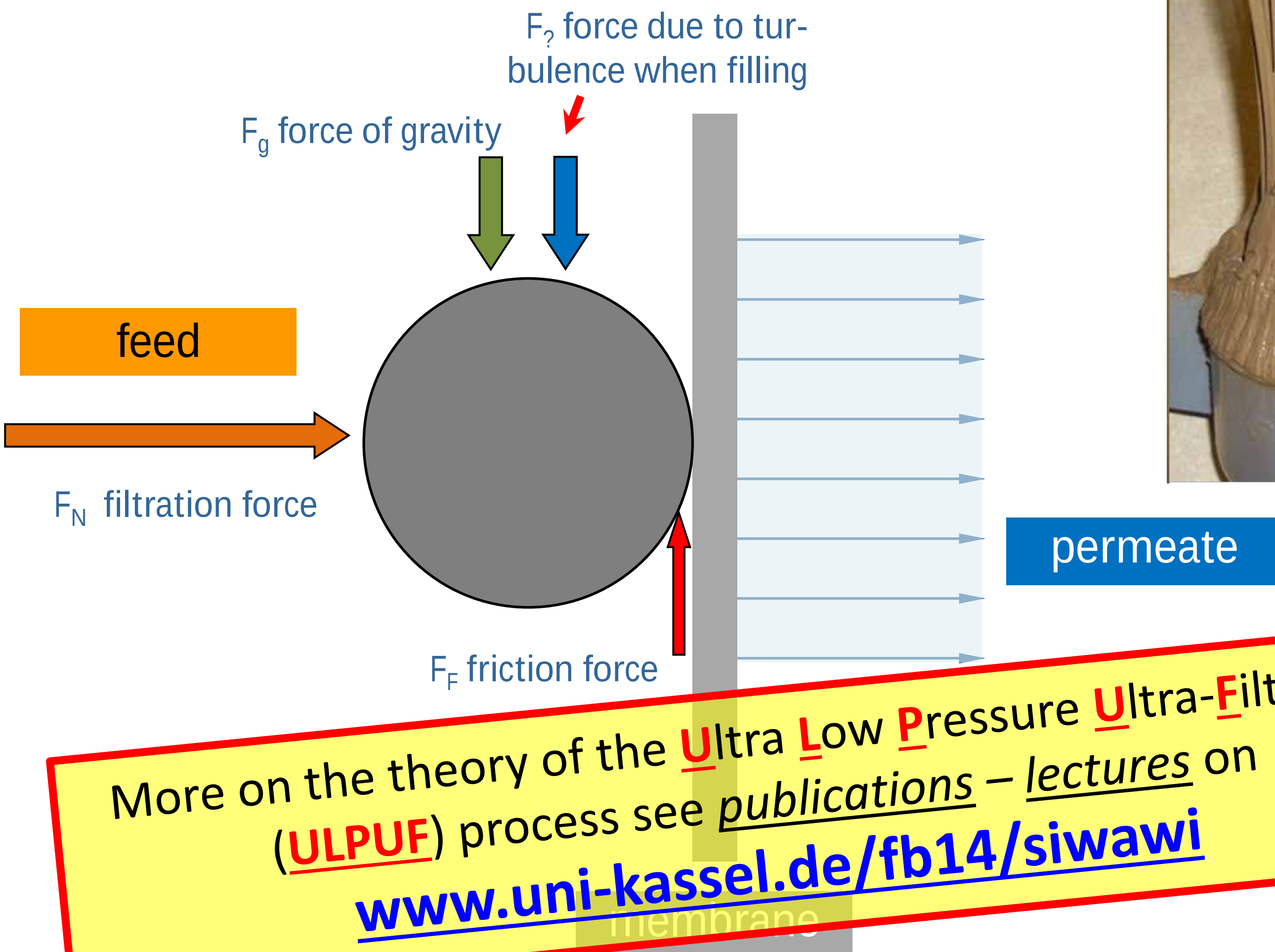
- Dead end filtration must have vertical membranes



More on the theory of the **U**ltra **L**ow **P**ressure **U**ltra-**F**iltration (**ULPUF**) process see *publications* – *lectures* on **www.uni-kassel.de/fb14/siwawi**

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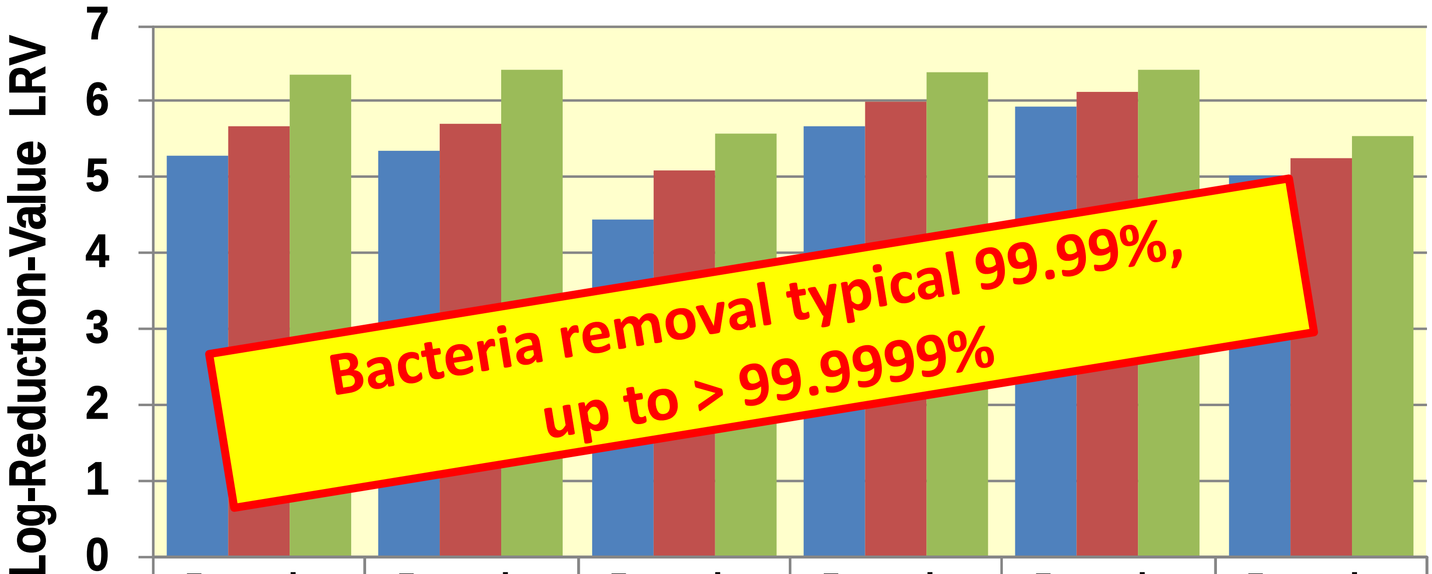
bacteria removal



	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

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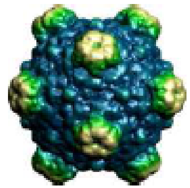
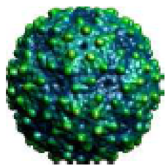
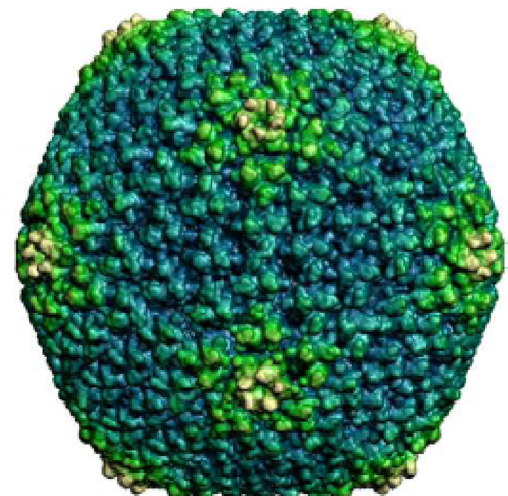
virus removal (Federal Environment Agency UBA)

- 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

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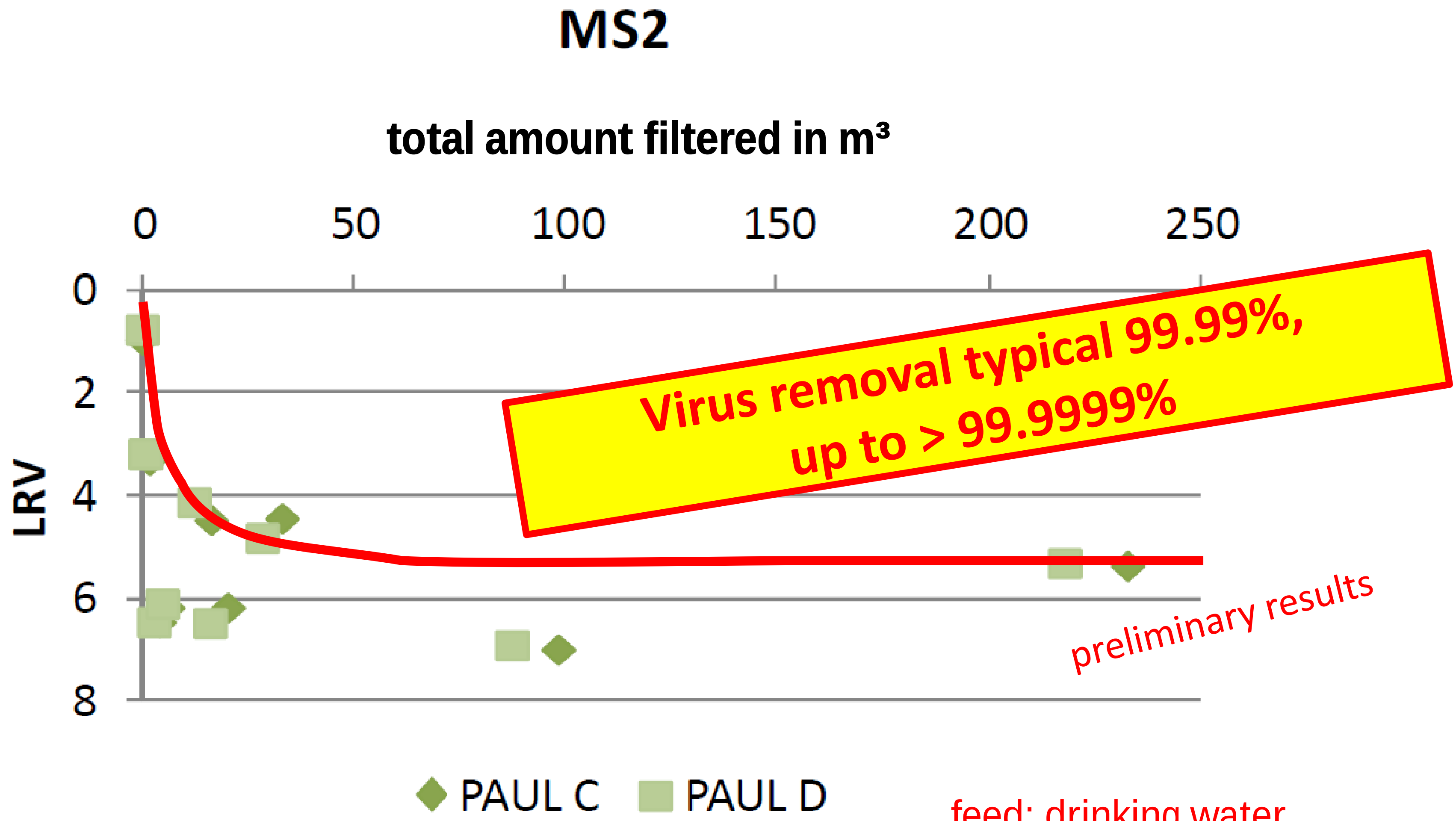
virus removal (Federal Environment Agency UBA)



feed: drinking water

analyzed by Federal Environment Agency, Dessau/Roßlau

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result ....

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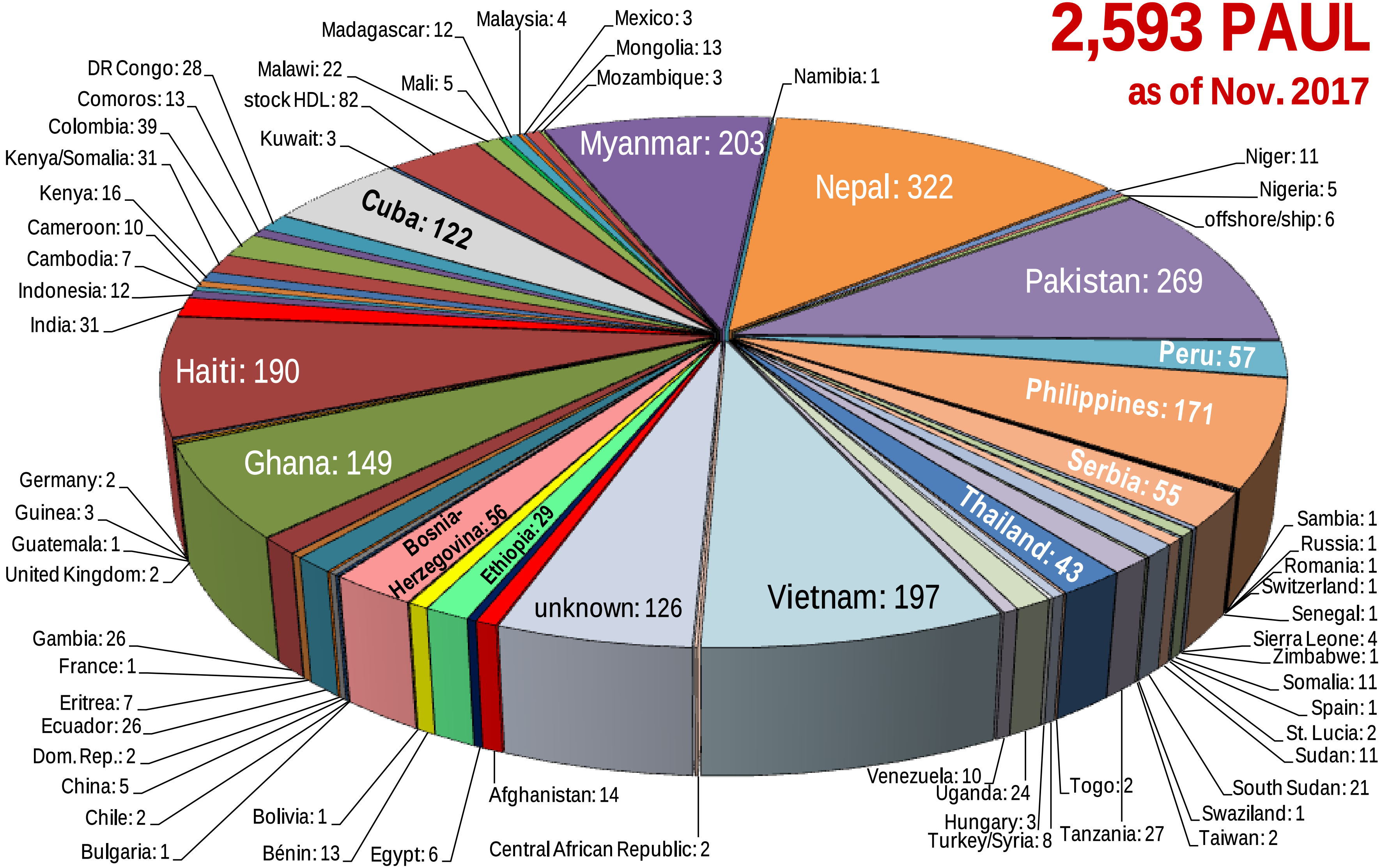
Distribution

2,593 PAUL

as of Nov. 2017



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Some organizations who brought **PAUL** into use

Auswärtiges Amt

HESSEN

Aktion Deutschland Hilft
Das Bündnis der Hilfsorganisationen

MEDECINS SANS FRONTIERES
ÄRZTE OHNE GRENZEN e.V.
Träger des Friedensnobelpreises

WUS
World University Service

German Rotary Volunteer Doctors e.V.

HDL
Hilfswerk der Deutschen Lions e.V.
LIONS FOUNDATION GERMANY

Help
Hilfe zur Selbsthilfe e.V.

action medeor
Deutsches Medikamenten Hilfswerk e. V.

welt hunger hilfe

medico international

AL-KHAIR FOUNDATION UK

stiftung nord-süd brücken

Festival de Colores

JOHANNITER-UNFALL-HILFE

LIONS INTERNATIONAL

SEWA

ChildFund Deutschland

Kinderhilfe Cusco-Peru e.V.

Kinderhilfswerk KHW Global-Care

ROTARY INTERNATIONAL

SOROPTIMIST INTERNATIONAL

terre des hommes
Hilfe für Kinder in Not

Bundesanstalt Technisches Hilfswerk THW

muslimehelfen

Children's Hope in Cambodia

Stiftung life

LIEBE IN AKTION
Ecclesia Missionswerk

humedica
INTERNATIONALE HILFE

Hand in Hand mit HAITI

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From PAUL (disaster) to PAUL Station (permanent supply)

- **PAUL** (assembled in Kassel Disabled Workshop) has a **lifetime of 10+ years**
- Thus, today, **PAUL** is used in two situations (maybe also consecutive):
  - **first aid in emergencies**. This was the original purpose **PAUL** was developed for, and **PAUL** still is a perfect tool for this purpose.

  - **permanent water supply**: as **PAUL** has such a long lifetime, and as all those who went into emergencies were left onsite, we decided to pay additional attention to its use as a permanent decentralized source of water.

    Of course it is not a good permanent solution to pour more than 100 buckets per day into the **PAUL** unit over years. Thus, with **PAUL Station**, we simply added a raw water tank and a fresh water tank, as is explained later on.

    Introducing a pump (eventually solar powered), no filling with buckets is necessary. All three tanks (raw water tank, **PAUL** and filtered water tank) are equipped with overfilling prevention measures (i.e. OPS, OPV and SV), which means that filtration can run **automatically and unattended day and night**.

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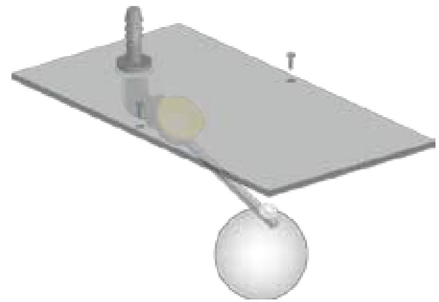
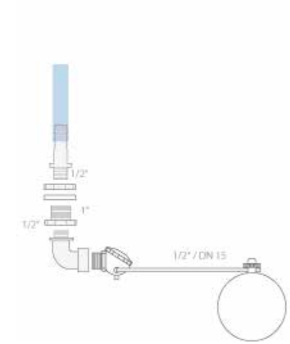
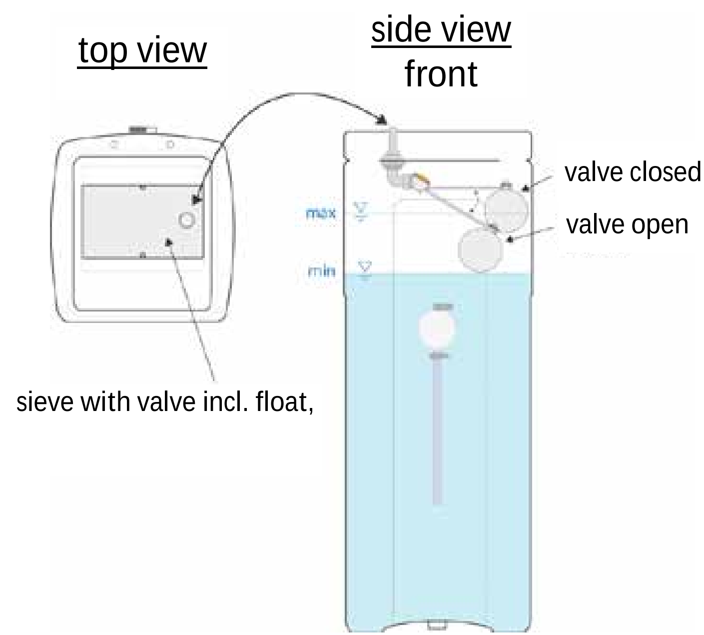
PAUL as permanent water supply







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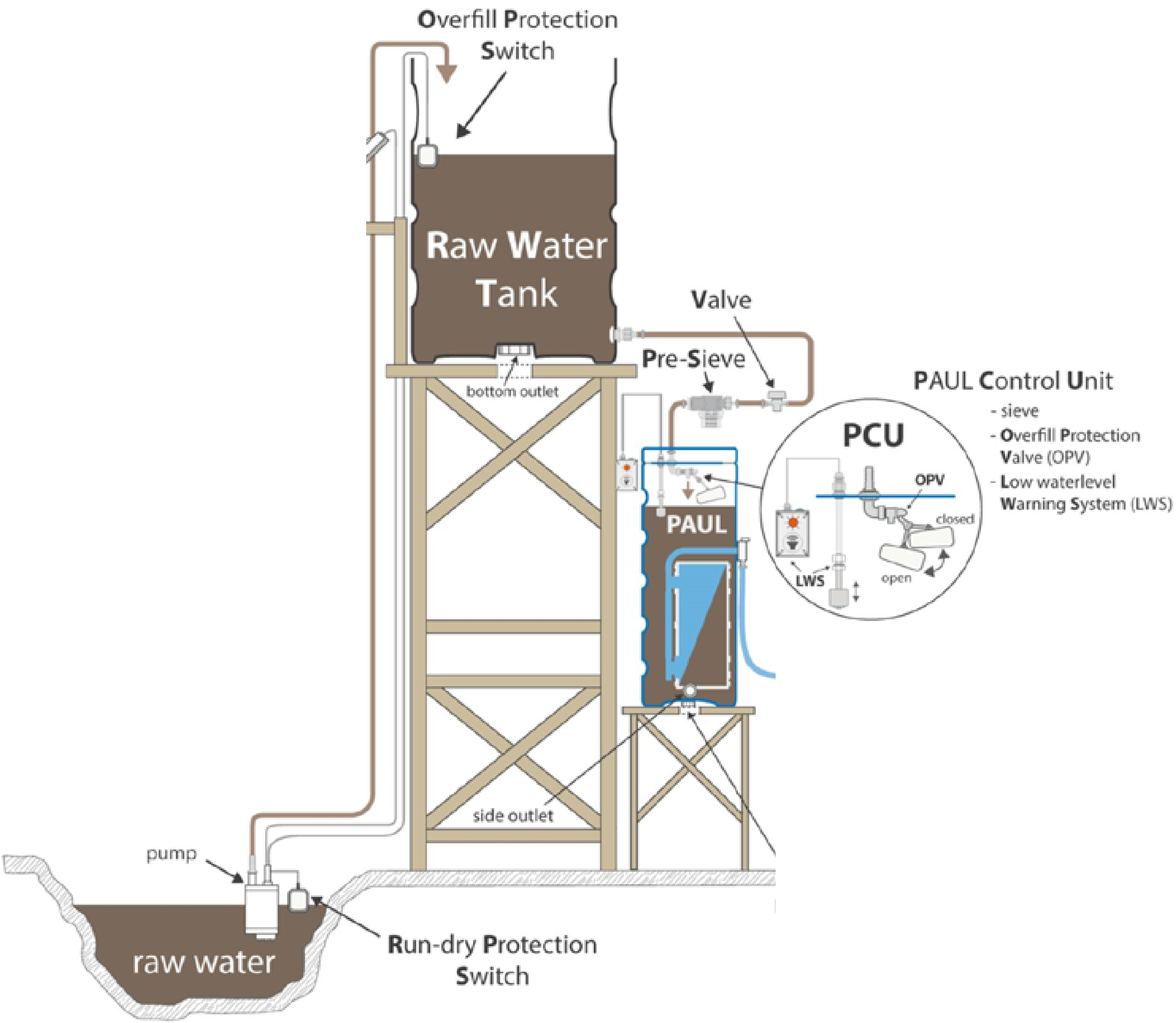
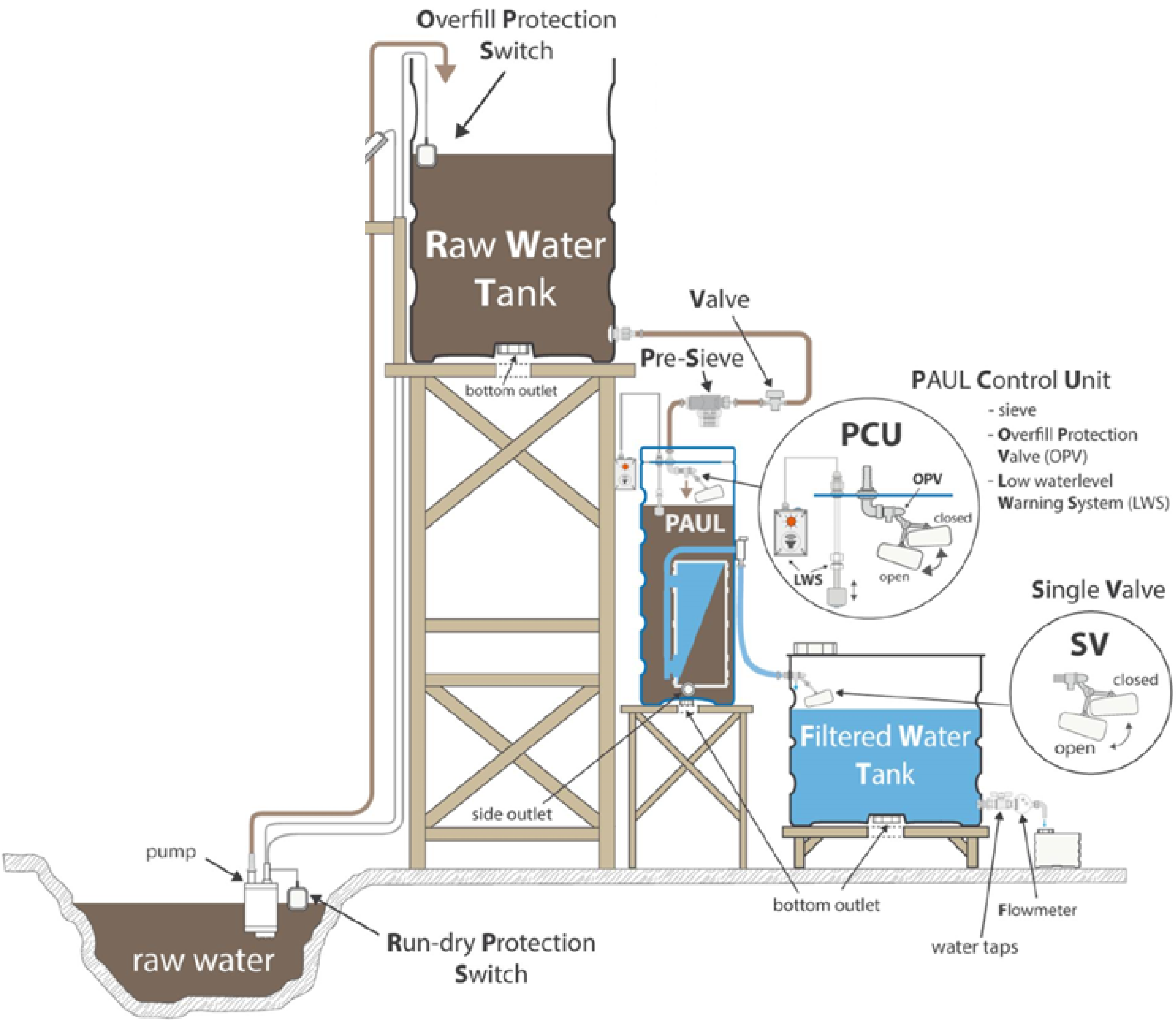
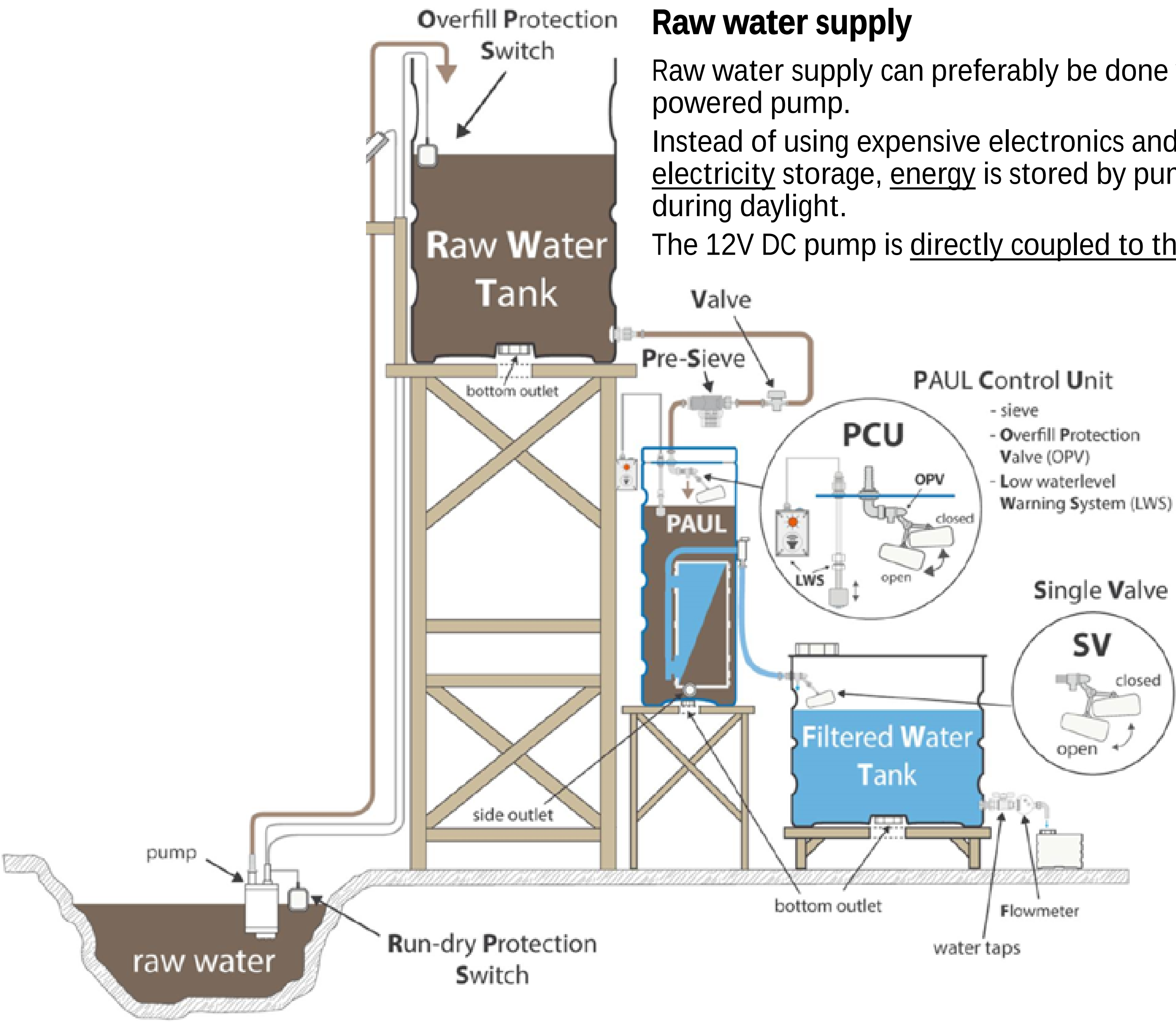
PAUL Station as permanent water supply



PAUL Station as permanent water supply



PAUL Station as permanent water supply



Raw water supply

Raw water supply can preferably be done with a solar powered pump.

Instead of using expensive electronics and batteries for electricity storage, energy is stored by pumping water during daylight.

The 12V DC pump is directly coupled to the solar panel.

PAUL Station as permanent water supply

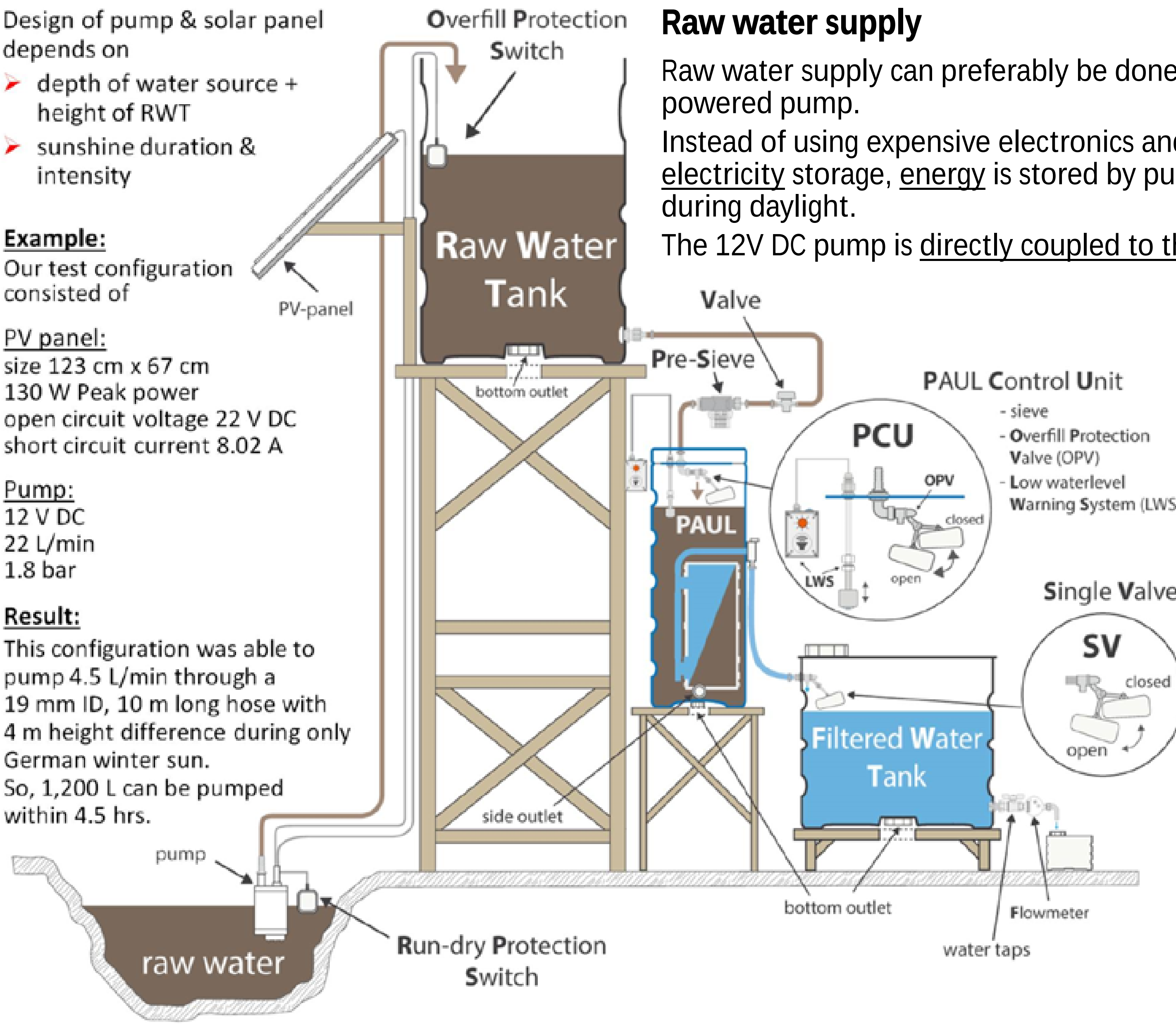
Design of pump & solar panel depends on
- depth of water source + height of RWT
- sunshine duration & intensity

Example:
Our test configuration consisted of

PV panel:
size 123 cm x 67 cm
130 W Peak power
open circuit voltage 22 V DC
short circuit current 8.02 A

Pump:
12 V DC
22 L/min
1.8 bar

Result:
This configuration was able to pump 4.5 L/min through a 19 mm ID, 10 m long hose with 4 m height difference during only German winter sun.
So, 1,200 L can be pumped within 4.5 hrs.



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Ghana – permanent supply

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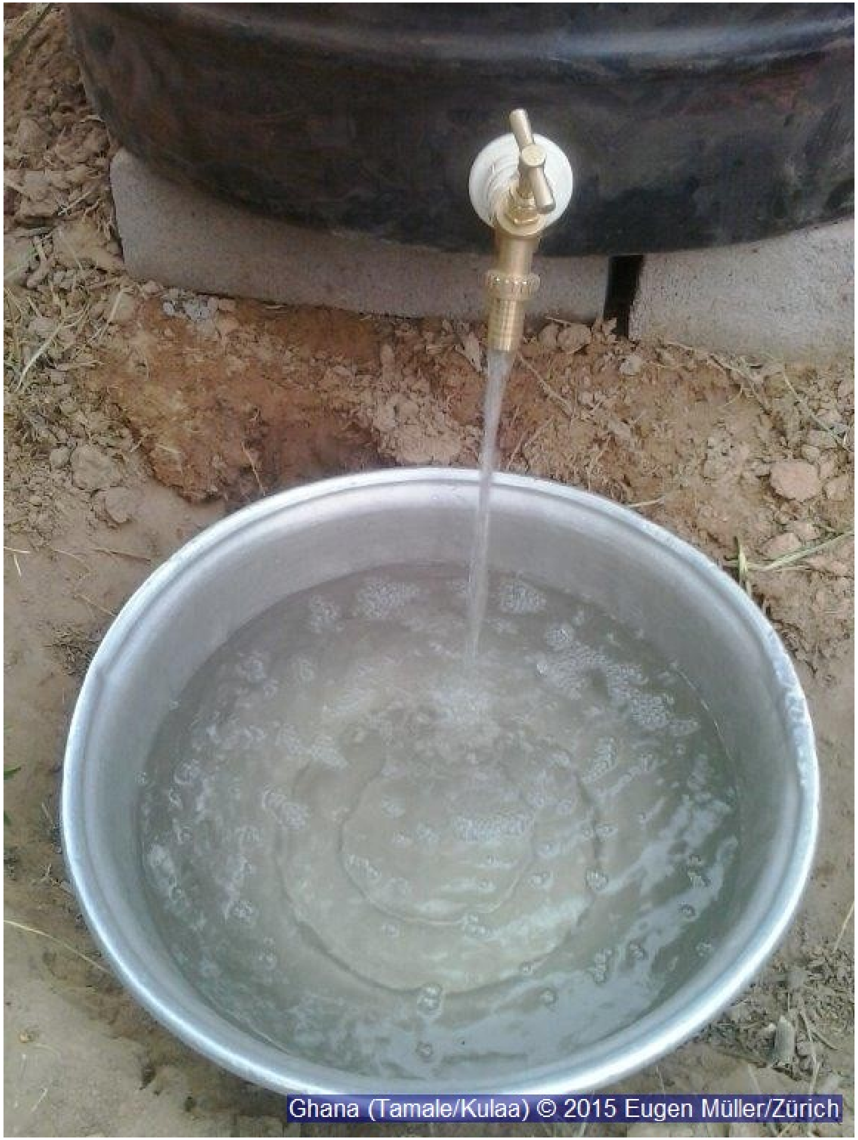
Ghana – permanent supply



Colombia – permanent supply

La Guajira

Cundinamarca

Nariño

Einsatzort	E.coli [KbE/100ml]		Trübung [NTU]		Färbung [Pt/Co]	
	Rohwasser	PAUL	Rohwasser	PAUL	Rohwasser	PAUL
C/marca	20	0	8,90	0,01	7	1
Cauca	6.000	0	7,83	0,01	39	1
La Guajira	3.000	0	40,70	0,01	28	11
Nariño	52	0	11,40	0,50	100	50

Nepal – permanent supply

India – permanent supply

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India – permanent supply

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India – permanent supply

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some additional but **very important facts**

- **PAUL** is assembled at **Kassel Disabled Workshop**
- No **spare parts import** necessary, as no cartridges etc. must be replaced on a regular basis
- No **waste of resources** concerning firewood, as boiling the water for disinfection is not necessary anymore
- **Plastic waste minimization**, as water will no longer be supplied in **plastic bottles**
- Dramatically reduced **cases of illness**, thus
  - less **cost** due to **illness**
  - less **cost** due to **inability to work**
  - less **absence from school = improved educational opportunities**
- **Local added value** by **creation of employment** as plant manufacturer/water vendor/plant operator/maintenance worker – **perfect for micro financing**

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PAUL Station – expenses estimated

Ü External cost (to be paid only once)

- Ä PAUL Station Kit (includes PAUL unit, PCU, SV, V, OPS, PS, freshwater meter and installation material): 1,300 € *
- Ä Transportation (ship/plane?): 200 €

1,500 €

Ü Local cost (build & operate 10 years)

- Ä Customs – depending upon country: 300 €
- Ä Build up PAUL Station: 600 €
  - Ø incl. local transport, RWT, FWT, stands for RWT, FWT & PAUL, hoses and parts, construction, pump, painting, start-up, wages, instructions for usage
- Ä **maintenance for 10 years** 600 €

1,500 €

- Ä Total cost (**10 years**): **3,000 €** (**50% local**)

* Only valid for humanitarian usage!

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PAUL Station – revenue and profit

Payback time (just an example):

- 60 families, paying 2 €/mon/family
- Lifetime revenue 60 x 2 x 12 x10 = 14,400 €
- Lifetime profit 14,400 € - 3,000 € = 11,400 €
- **Payback time = 2.6 years**

Water price (under the above conditions):

- Min. lifetime production: **1,200 L/d** x 365 d x 10 a = **4,380,000 L**
- Results in a price of 0.0**033 €/L**
- Currently (Sept. 2016), one 20 L water can at the Tamil Nadu coastline (India) costs 30 Rs:
  1.5 Rs/Liter **=** 0.0**200 €/L** (more than **6 times** more)

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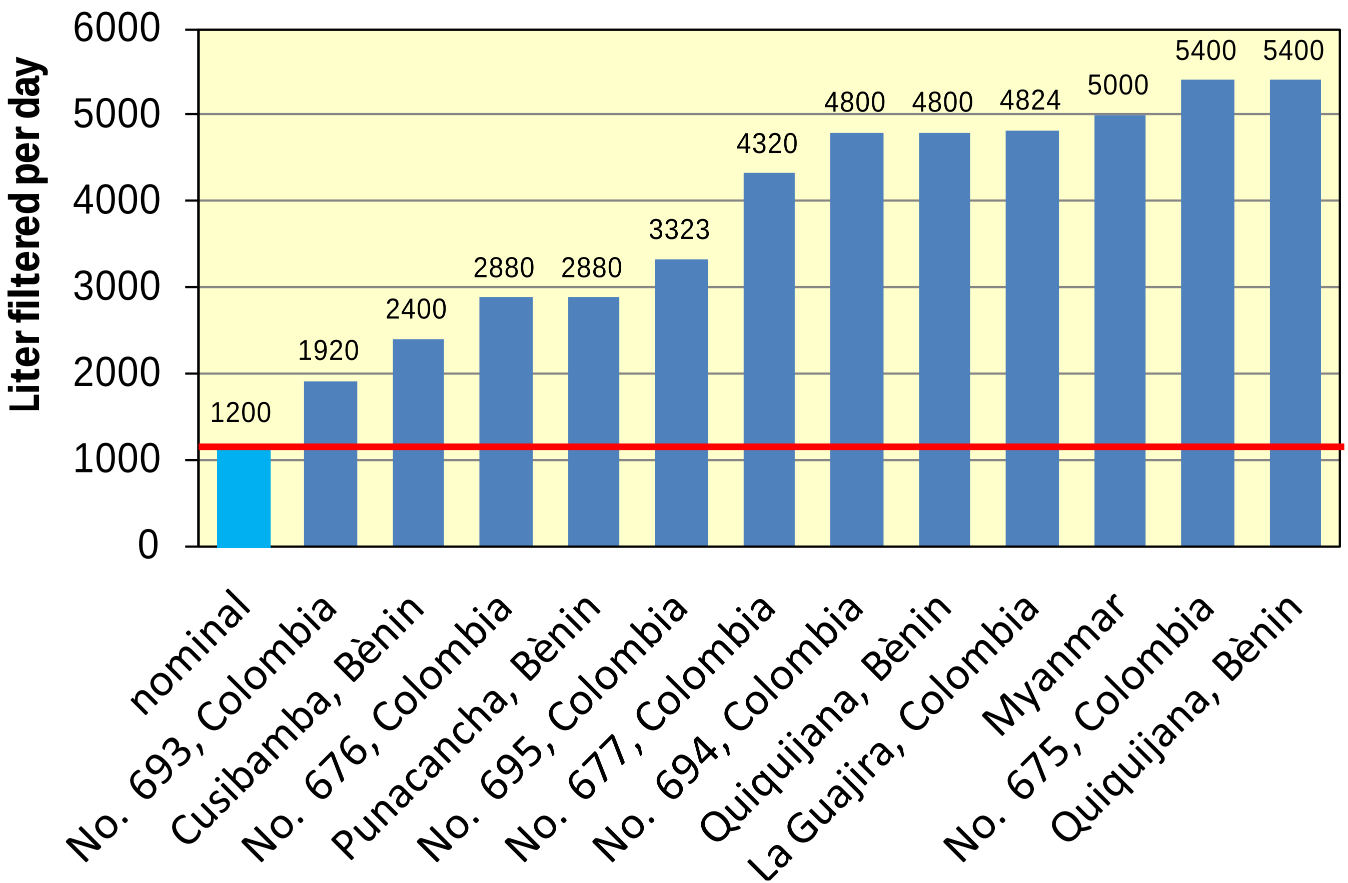
Remark on field inspections of **PAUL**

- in practice, the daily flow is far beyond our design value of 1,200 L/d, mostly in the range **between 1,900 L/d and 5,400 L/d**) which gives a **shorter payback time** and a **lower water price**

Recent results:
2 installations,
March 2016
in India:

- Measured 19 Sept. '16 in Puthanthurai: **2,500 L/day**
- Measured 20 Sept. '16 in Pallam: >6,000 L/day



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Essential:

It is essential that local people can improve their <u>health</u> and <u>wealth</u> <u>by themselves</u> after a simple introduction – no dependency on import of spare parts/consumables!

Independently providing water and creating local jobs is the best way to improve conditions and prevent migration.

CAPACITY DEVELOPMENT!

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cloud: https://www.dropbox.com/sh/hcrg8fui0lttkqt/AAAcKt0m66p8JQdz19vtldbta?dl=0

Thank you for your attention – and: Spread the knowledge about PAUL !

© Humanity Care Foundation

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

AQUA AWARD 2017
AQUANET BERLIN BRANDENBURG

GreenTec Awards
WINNER 2016
Water & Sewage

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