WaterBackpack "PAUL®" for disasters and for permanent water supply

General information about **PAUL®** and **PAUL®** stations

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Deutsche Bundesstiftung Umwelt

www.dbu.de

Franz-Bernd Frechen, IWA Fellow

Chair, IWA Specialist Group „Membrane Technology“ 2014-2017

Chair, DWA Committee on „Membrane Bioreactors“ until 2018

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overview

- Some basics on water in the world
- Principles of **PAUL®**
- **PAUL®** standard units in emergencies and for “simple” permanent water supply
- How does a **PAUL® station** look like?
- examples of **PAUL® station** for permanent supply
- economics
- rainwater ponds as a raw water source

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Facts – World Water Development Report 2019 et al.

- **8 billion** people live worldwide
- "Three out of ten people do not have access to safe drinking water."
  ... this means: **2.4 billion** people
- "However, these global figures mask significant inequities between and within regions, countries, communities and even neighbourhoods"
  ... this means also: more than **80%** live in **rural areas** (www.washdata.org)

All phrases in quotes: **World Water Development Report 2019**

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Sustainable Development Goals (SDG)

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

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rationale for **PAUL**

- Membranes are able to retain **bacteria**. So why not use membranes to retain bacteria and pathogens, the **most serious concern in disasters**?
- The original task of our research, **starting in 2001**, was to create a **small** unit that provides **potable water** in **emergencies**, characterized by
  - No **energy** needed – gravity driven
  - No **chemicals** needed
  - Simple & robust
  - No or nearly no **maintenance** needed
  - Operational even for **illiterates**
  - **easily transportable**, even hands-free as a **backpack**
  - Designed to help in **emergencies** and **disasters**
- The result was the waterbackpack **"PAUL"**, a **research project** mainly financed by the **German Federal Environmental Foundation DBU**

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operation principles **PAUL**

- gravity driven **dead end filtration** with **vertical flat sheet membranes (see next slide)**
- **ULP-UF: ultra low pressure ultrafiltration: max. 0.08 bar**
  - pore blocking: close to zero
  - cake layer removal: by **gravity** (sinks to the bottom and then to be removed)
  - process: **pressure operated** (instead of usual flow driven process)
- ≈ 10 m² membrane surface area, **lifetime 10+ years**
- Min. capacity 1,200 L/d, practical measurements from **2,000 to 6,000 L/d, see**
- **extremely simple**
- **no spare parts necessary**

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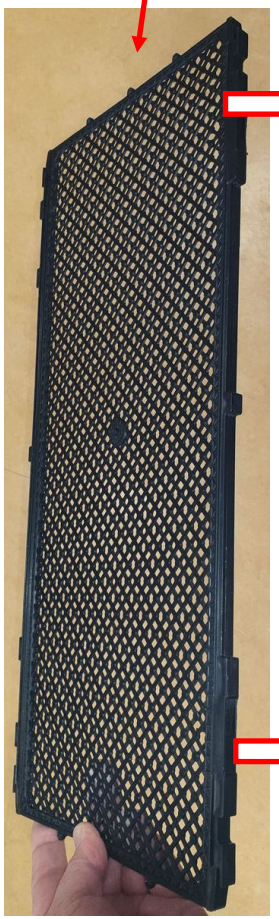
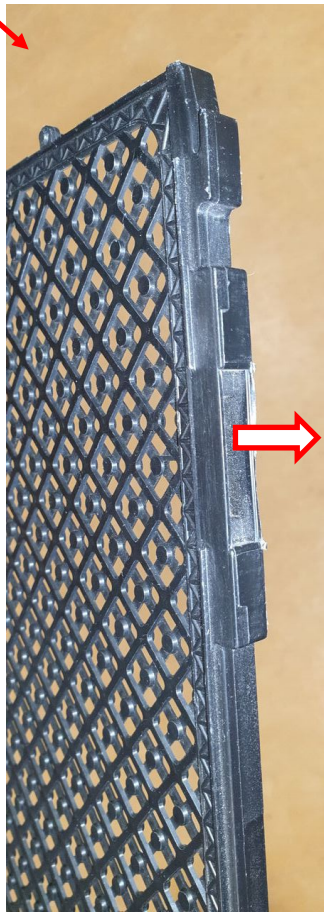
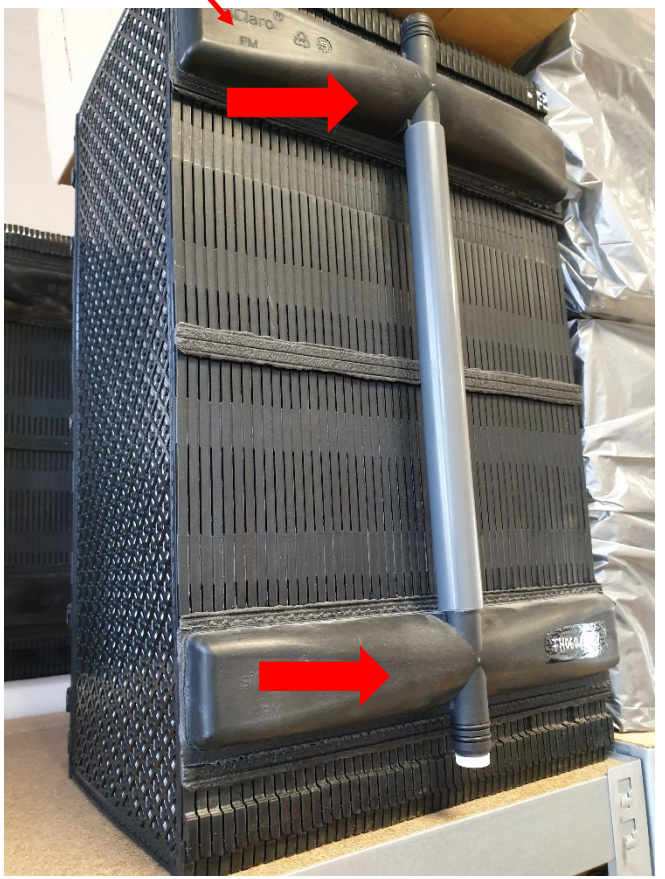
flat sheets and membrane module

- Flat sheet – flat sheet with membranes – membrane module (50 flat sheets)







⇨ outlet from flat sheet (2 per sheet)

➡ filtered water collection channel

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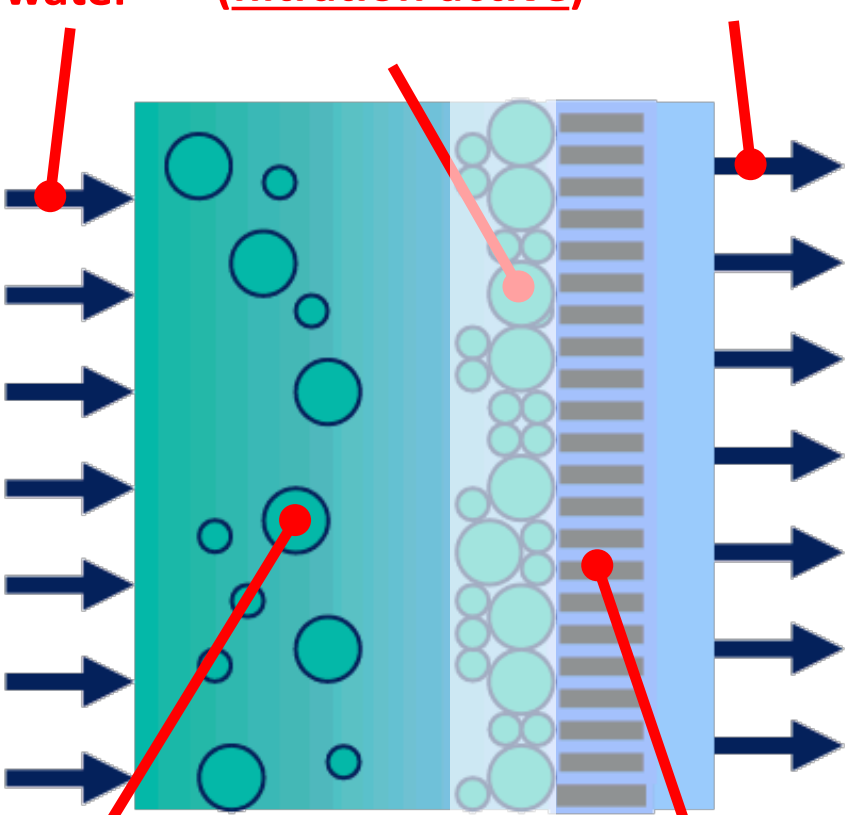
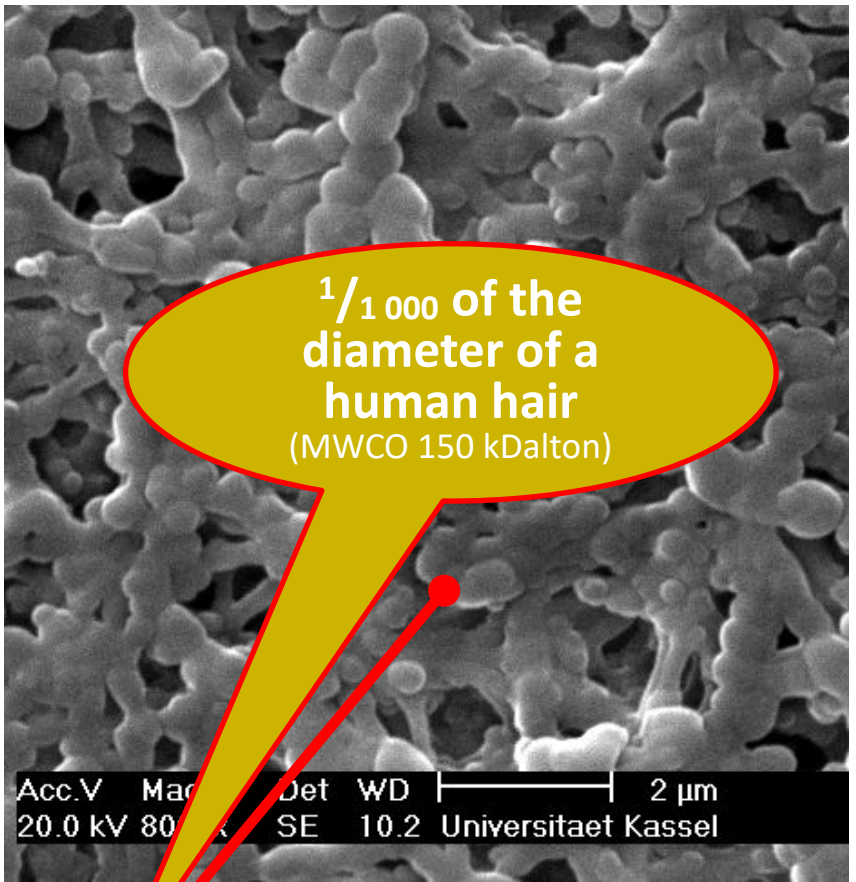
filtration is mostly done by the **cake layer**





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

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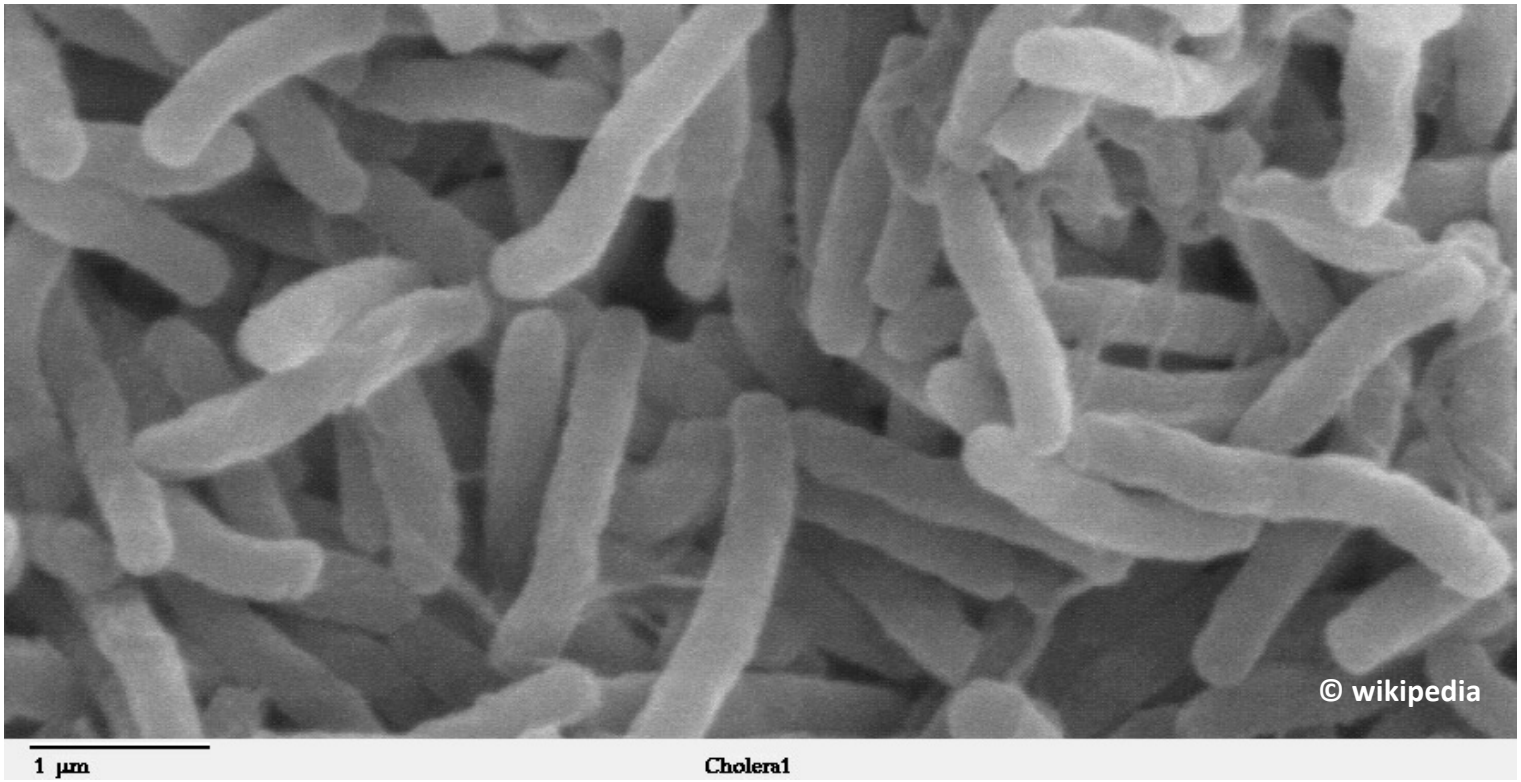
removal of bacteria, example cholera



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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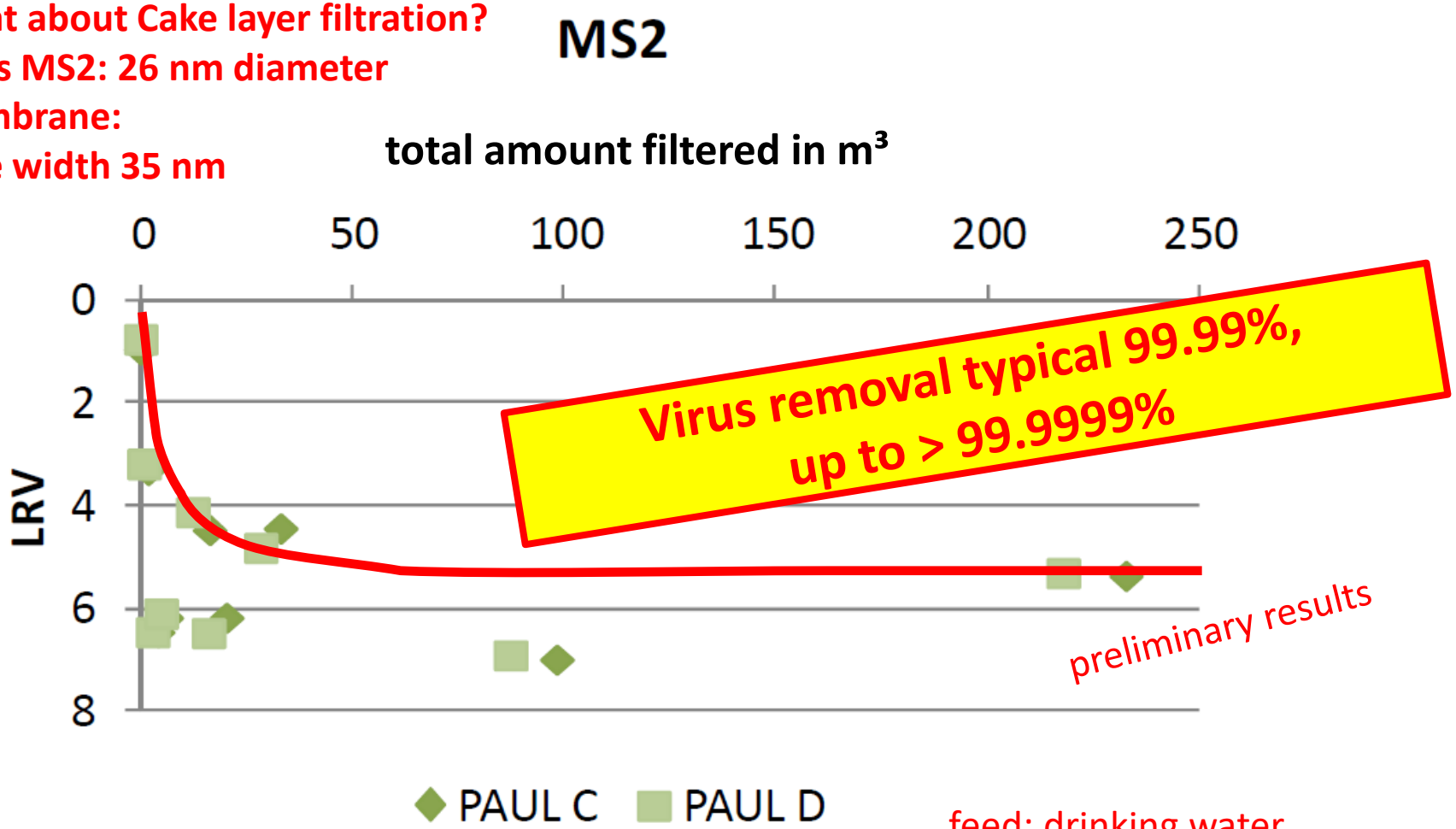
bacteria removal

	Fresenius e.coli ISO 9308-1 PAULA	Fresenius coliforme ISO 9308-1 PAULA	Fresenius I.E. ISO 7899-2 PAULA	Fresenius e.coli ISO 9308-1 PAULB	Fresenius coliforme ISO 9308-1 PAULB	Fresenius I.E. ISO 7899-2 PAULB
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

virus removal (Federal Environment Agency UBA)

What about Cake layer filtration?
Virus MS2: 26 nm diameter
membrane:
pore width 35 nm



feed: drinking water

analyzed by Federal Environment Agency, Dessau/Roßlau

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result ....

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a first test in India 2010 ... street water

... and the result

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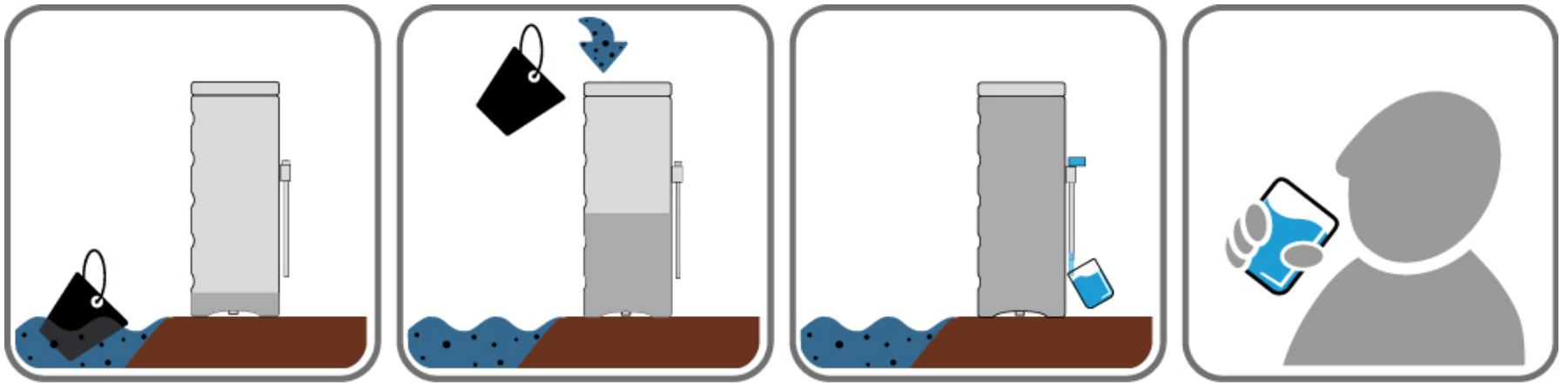
The complete operation manual (in emergencies)

- no moving parts, no energy, no chemicals, no maintenance , extremely robust, to be operated by anyone – even illiterates
- See the complete operation manual!



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P ortable
A qua
U nit for
L ifesaving

PAUL® is assembled at the Kassel Disabled workshop

Sozialgruppe Kassel e.V.

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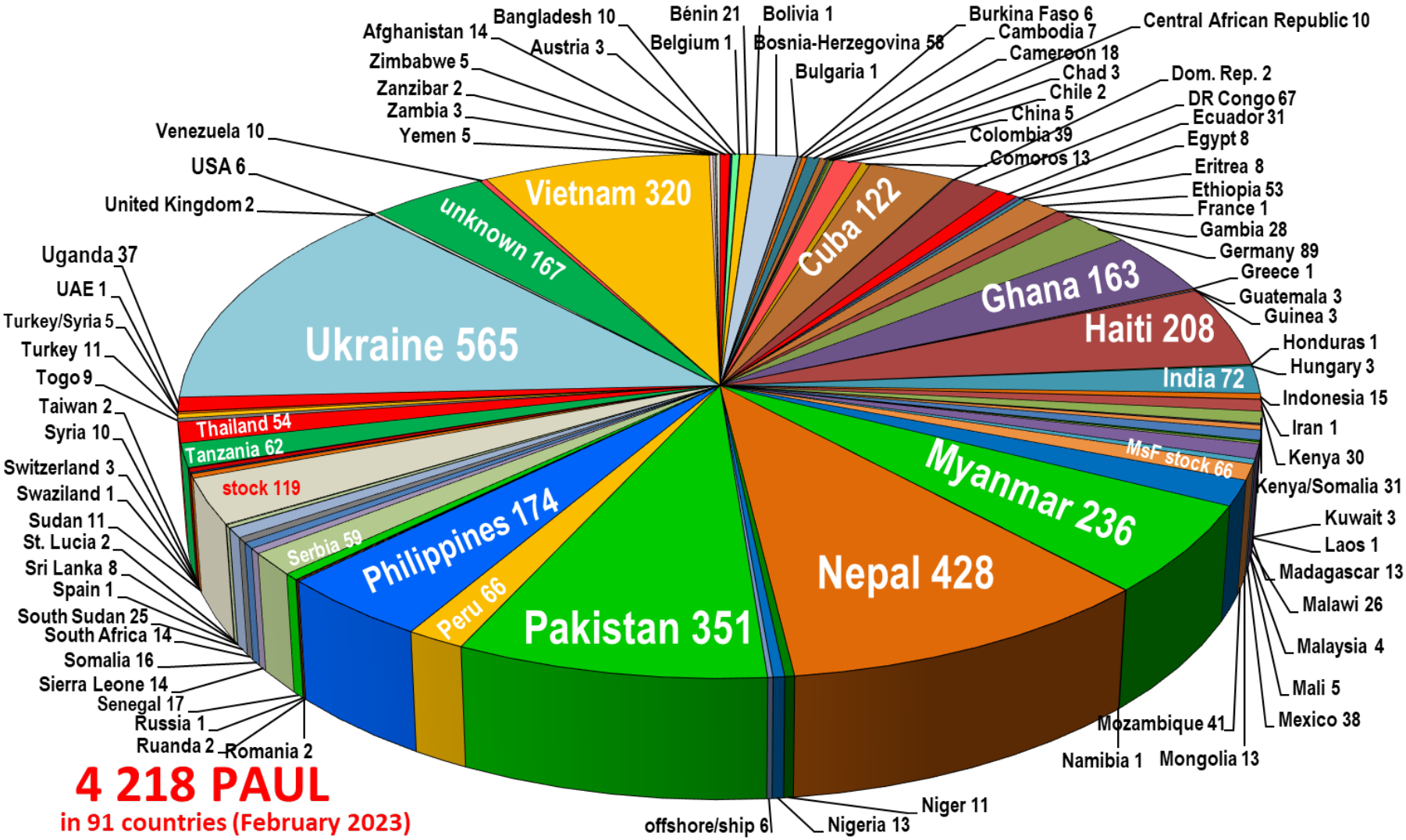
Distribution



4 218 PAUL
in 91 countries (February 2023)

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Some organizations who brought **PAUL** into use

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PAUL® standard units in emergencies and for “simple” permanent water supply

In many locations, **PAUL®** standard units that originally were distributed due to a disaster or emergency situation are still in use for “simple” permanent water supply after the disaster or emergency situation is over.

In several other situations not related to disasters, **PAUL®** standard units are introduced for “simple” permanent water supply.

In both cases, however, **PAUL®** standard units are filled with buckets, in contrary to the **PAUL® station** arrangement that is shown later.

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

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

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PAUL® as first aid or “simple” permanent supply

Pakistan 2010 © Humanity Care Foundation

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Niger © TAMAT e.V.

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PAUL® as first aid or “simple” permanent supply

- installed in Tanzania March 2012
- since then, **no more cases** of diarrhea, cholera or other waterborne diseases according to locals

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PAUL® as first aid or “simple” permanent supply

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How does a **PAUL® station** look like?

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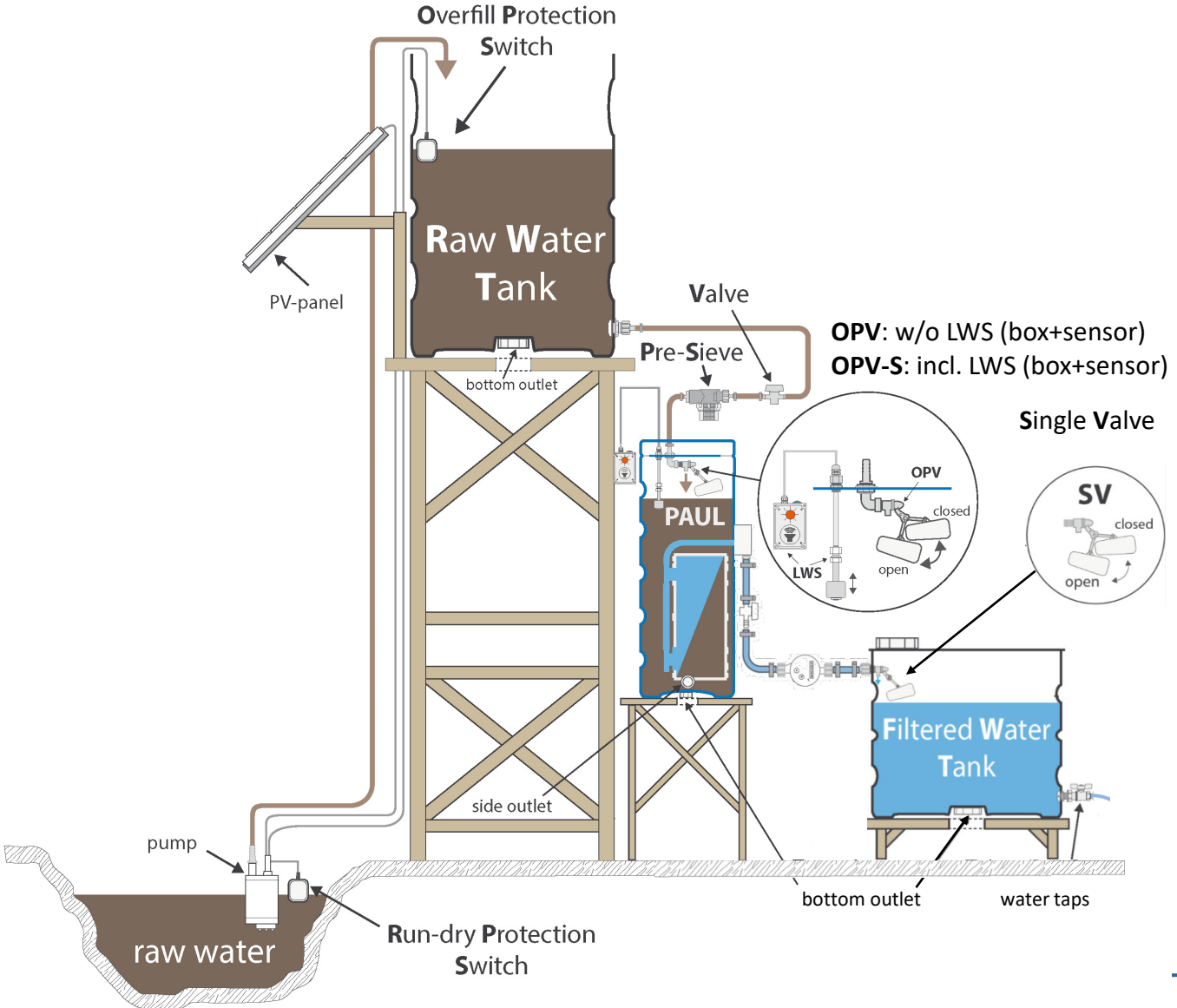
PAUL® station for permanent water supply



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PAUL® station for permanent water supply

Raw water supply

Raw water supply can preferably be done with a solar powered pump. The design depends on

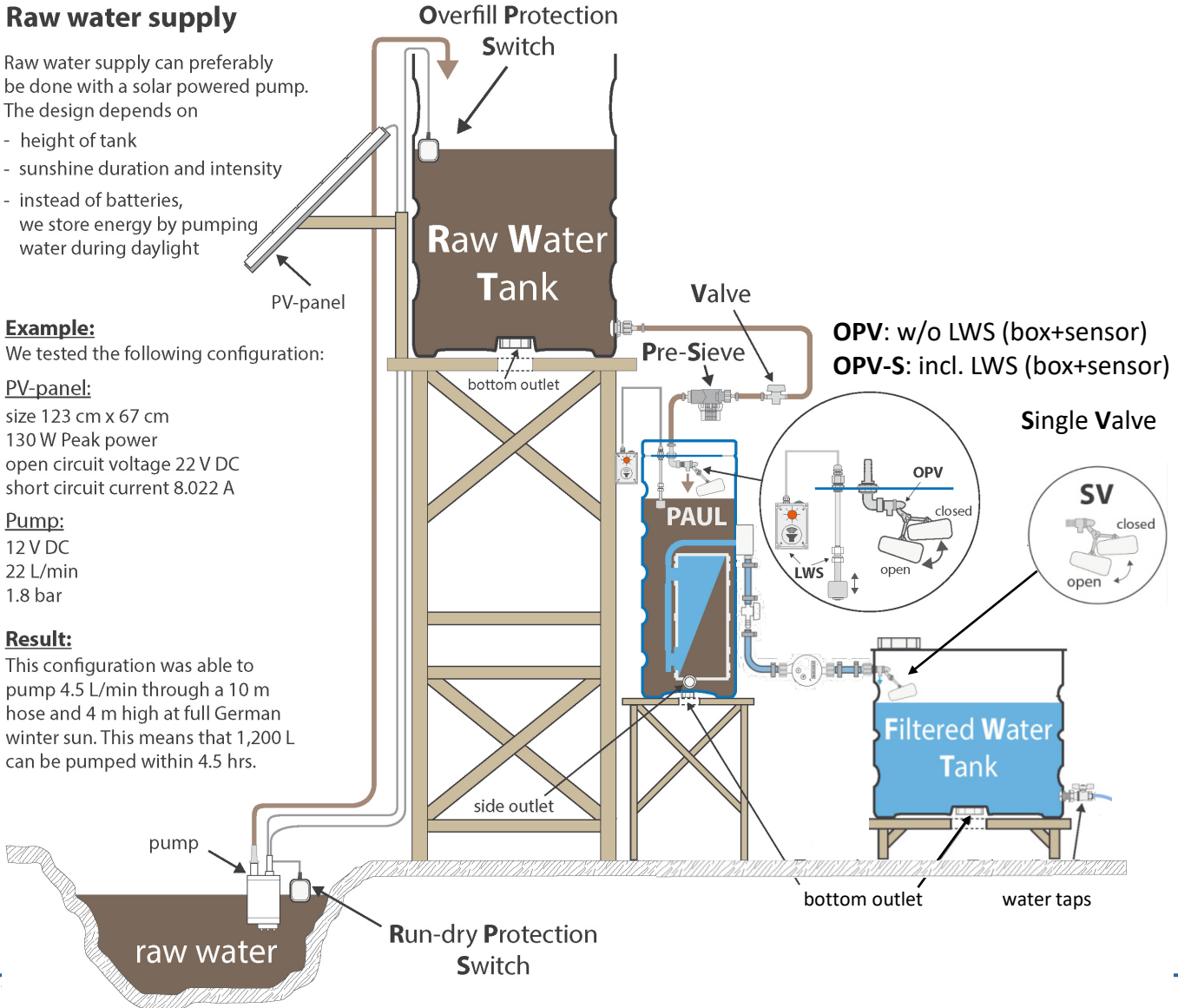
- height of tank
- sunshine duration and intensity
- instead of batteries, we store energy by pumping water during daylight

Example:
We tested the following configuration:

PV-panel:
size 123 cm x 67 cm
130 W Peak power
open circuit voltage 22 V DC
short circuit current 8.022 A

Pump:
12 V DC
22 L/min
1.8 bar

Result:
This configuration was able to pump 4.5 L/min through a 10 m hose and 4 m high at full German winter sun. This means that 1,200 L can be pumped within 4.5 hrs.



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examples of **PAUL® station** for permanent supply

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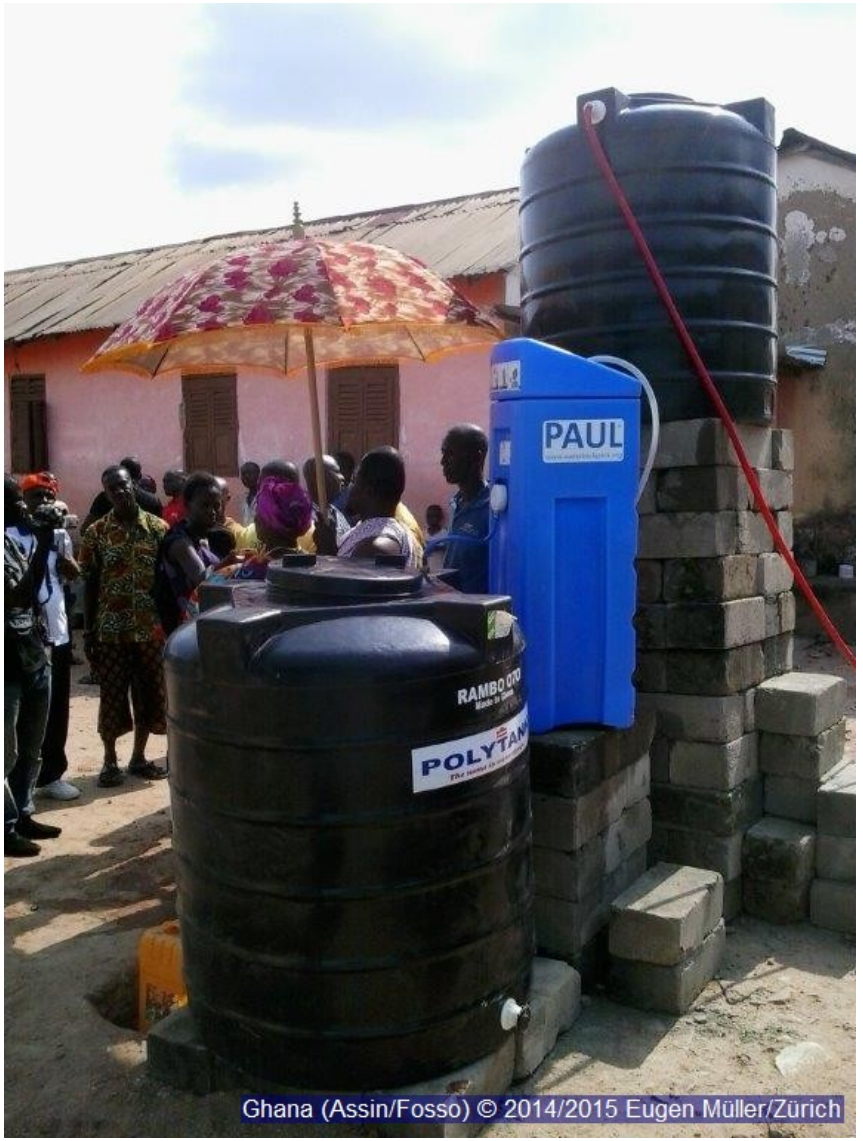
examples of PAUL® station



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examples of PAUL® station

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examples of **PAUL®** station

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examples of PAUL® station

Tanzania © Hans-Ludwig Rau 2019

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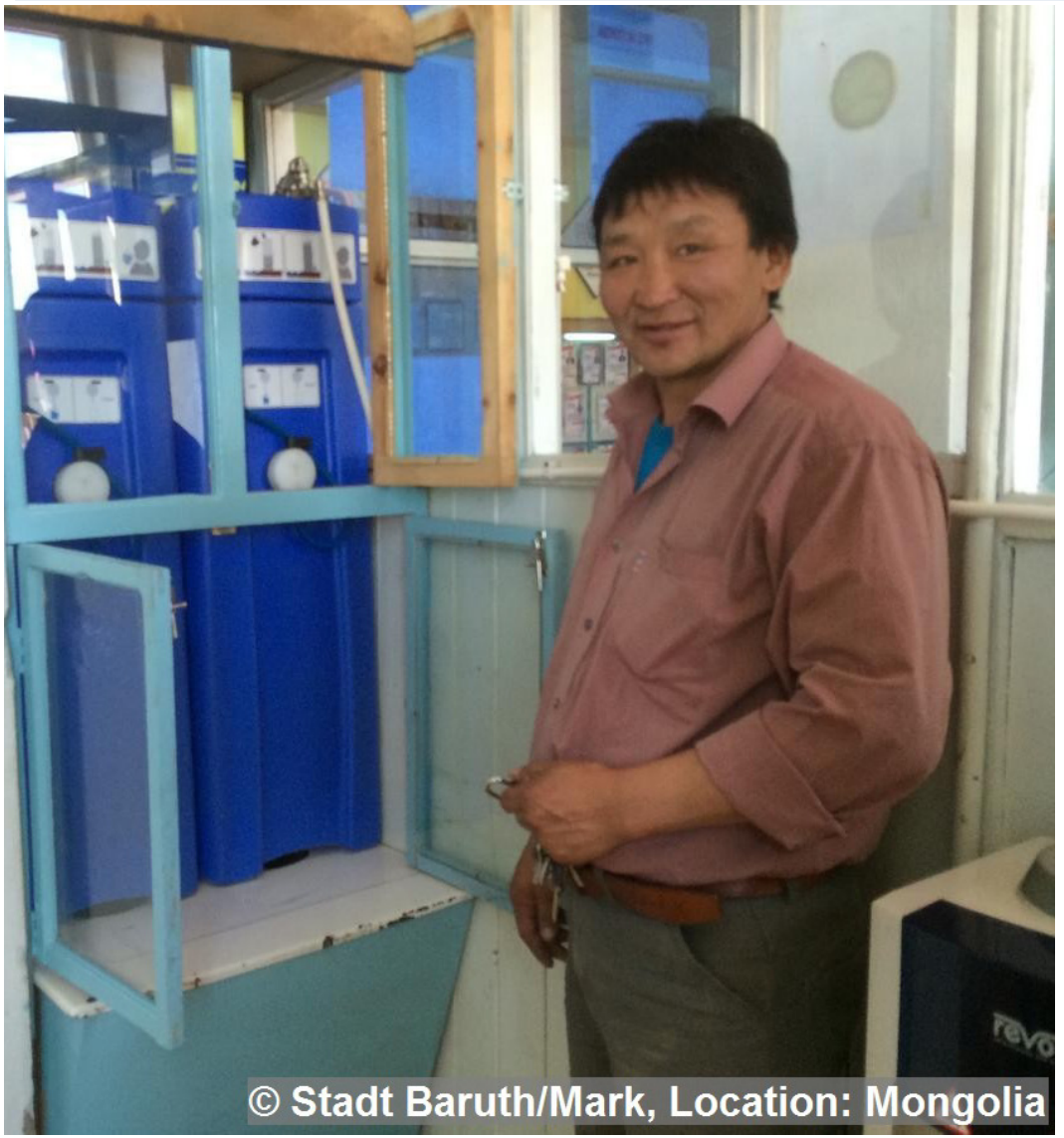
examples of PAUL® station



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examples of PAUL® station

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Vietnam 2018 © World University Service

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examples of PAUL® station

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examples of PAUL® station

Total cost of local installation:
600 Euro (2020)

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examples of PAUL® station

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examples of PAUL® station

Total cost of local installation (no stands, no pump necessary):
380 Euro (2016)
(this & next slide)

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examples of PAUL® station

Total cost of local installation (no stands, no pump necessary):
380 Euro (2016)
(this & previous slide)

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PAUL® station step by step (1): Enayam Puthenthurai

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PAUL® station step by step (2): Enayam Puthenthurai

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PAUL® station step by step (3): Enayam Puthenthurai

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PAUL® station step by step (4): Enayam Puthenthurai

Visit onsite in Jan. 2020 revealed that locals still are extremely happy with the installation

Total cost of local installation incl. stand, tanks, electric AC pump etc. :
790 Euro (2016)

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examples of PAUL® station

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usage for permanent supply: how to set up a local business

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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
- **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

External cost (to be paid only once)

- PAUL Station Kit (includes PAUL unit, PCU, SV, V, OPS, PS, freshwater meter and installation material): 115,000 Rs *
- Transportation (ship): 5,000 Rs

Local cost

- Customs – depending upon country: 30,000 Rs
- Build up PAUL Station: 60,000 Rs
  - incl. local transport, RWT, FWT, stands for RWT, FWT & PAUL, hoses and parts, construction, pump, painting, start-up, wages, instructions for usage
  - **incl. Maintenance 10 years** 30,000 Rs
- Total cost: **240,000 Rs** (**50% local**) **= 3,000 €** **= 25 €/month**

* Only valid for humanitarian usage!

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PAUL Station – earnings and profit

- Lifetime production: **1,200 L/d** x 365 d x 10 a = **4,380,000 Liter**
- One 20 L water can at the Tamil Nadu coastline costs 30 Rs: 1.5 Rs/Liter **= 0.02 €/Liter**
- Sell PAUL Station water for **1/4 of that price = 0.005 €/Liter**
- Lifetime value feasible: 4,380,00 x 0.005 **= 21,900 €/10 yrs**
- Lifetime profit feasible: 21,900 – 3,000 **= 18,900 €/10yrs**
- Or **158 €/month** (183€/month minus 25 €/month payback)

- Why not operate 20 PAUL Stations (and become a water businesswoman / businessman) ??

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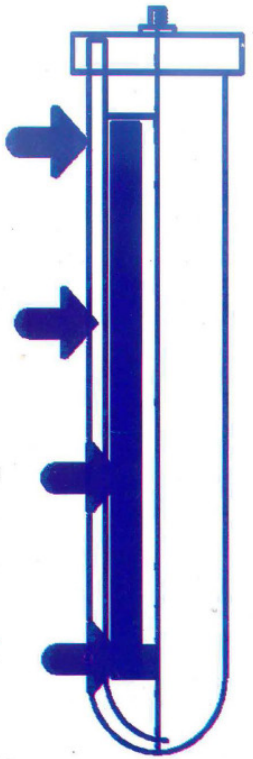
This filter is cheaper (only 20 €) ... or??

Section of Filter Element



Outer Shell - Micro Filtration

Anti-Bacterial formula within the ceramic natrix kills pathogens

Activation carbon takes out chlorine and organics improving taste and odour

Also contains heavy metal removal media, which takes out toxic lead

HANDS is a one of the largest & leading NPO of country, working since 1979 in health, education, poverty alleviation, water and sanitation, infrastructure development, emergency response through social mobilization, advocacy & capacity building. HANDS is benefiting more than 19000 villages in 24 districts of Pakistan.

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Portable Ceramic Water Filter

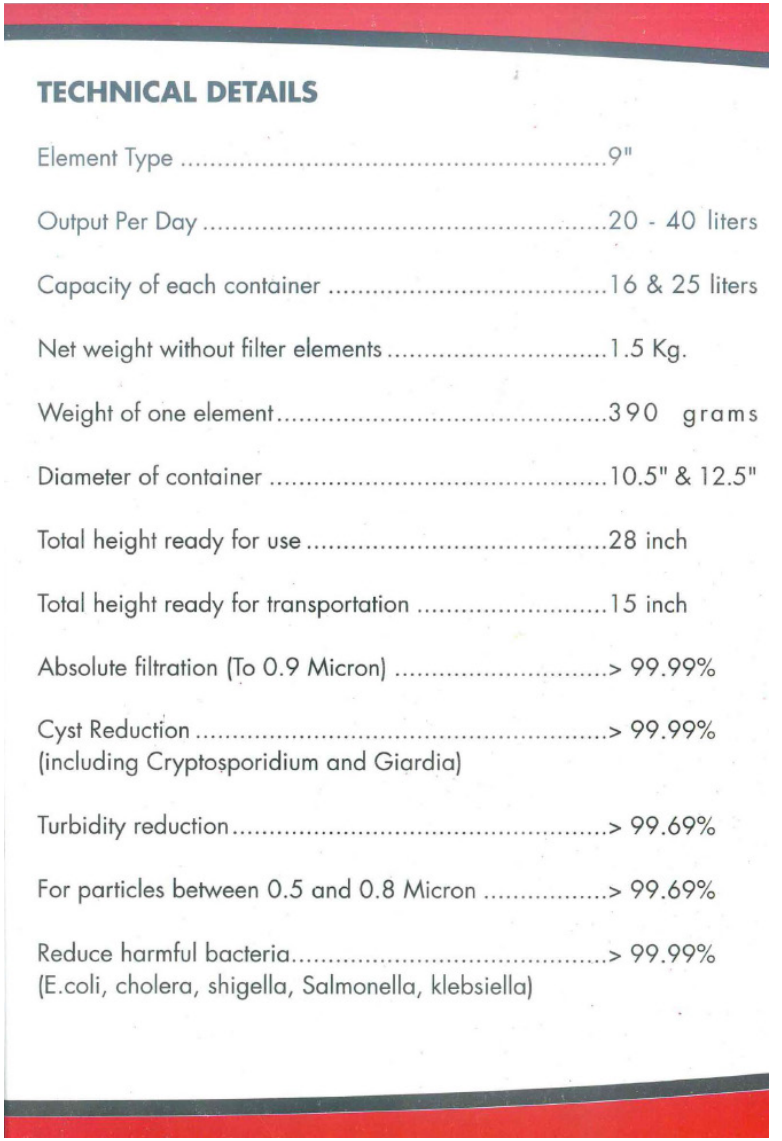
HANDS Infrastructure Development, Energy, WASH and Shelter (IDEAS) Program

140-C, Block II, PECHS, Karachi. Tel: (021) 34532804, 34527698 Fax: (021) 34559252
Email: info@hands.org.pk Web: www.hands.org.pk

This filter is cheaper (only 20 €) ... or??

- 1 year lifetime
- 20 € per Filter

- In order to replace 1 **PAUL**:
- 30-60 units (to provide 1,200 L/d)
- 300-600 units (for 10 years)
- That‘s an invest of **6,000 € to 12,000 €**
- **PAUL**: only **3,000 €** incl. maintenace, tanks, pump, solar panel and maintenance – all in all for **10 years**



TECHNICAL DETAILS

Element Type	9"
Output Per Day	20 - 40 liters
Capacity of each container	16 & 25 liters
Net weight without filter elements	1.5 Kg.
Weight of one element	390 grams
Diameter of container	10.5" & 12.5"
Total height ready for use	28 inch
Total height ready for transportation	15 inch
Absolute filtration (To 0.9 Micron)	> 99.99%
Cyst Reduction (including Cryptosporidium and Giardia)	> 99.99%
Turbidity reduction	> 99.69%
For particles between 0.5 and 0.8 Micron	> 99.69%
Reduce harmful bacteria (E.coli, cholera, shigella, Salmonella, klebsiella)	> 99.99%

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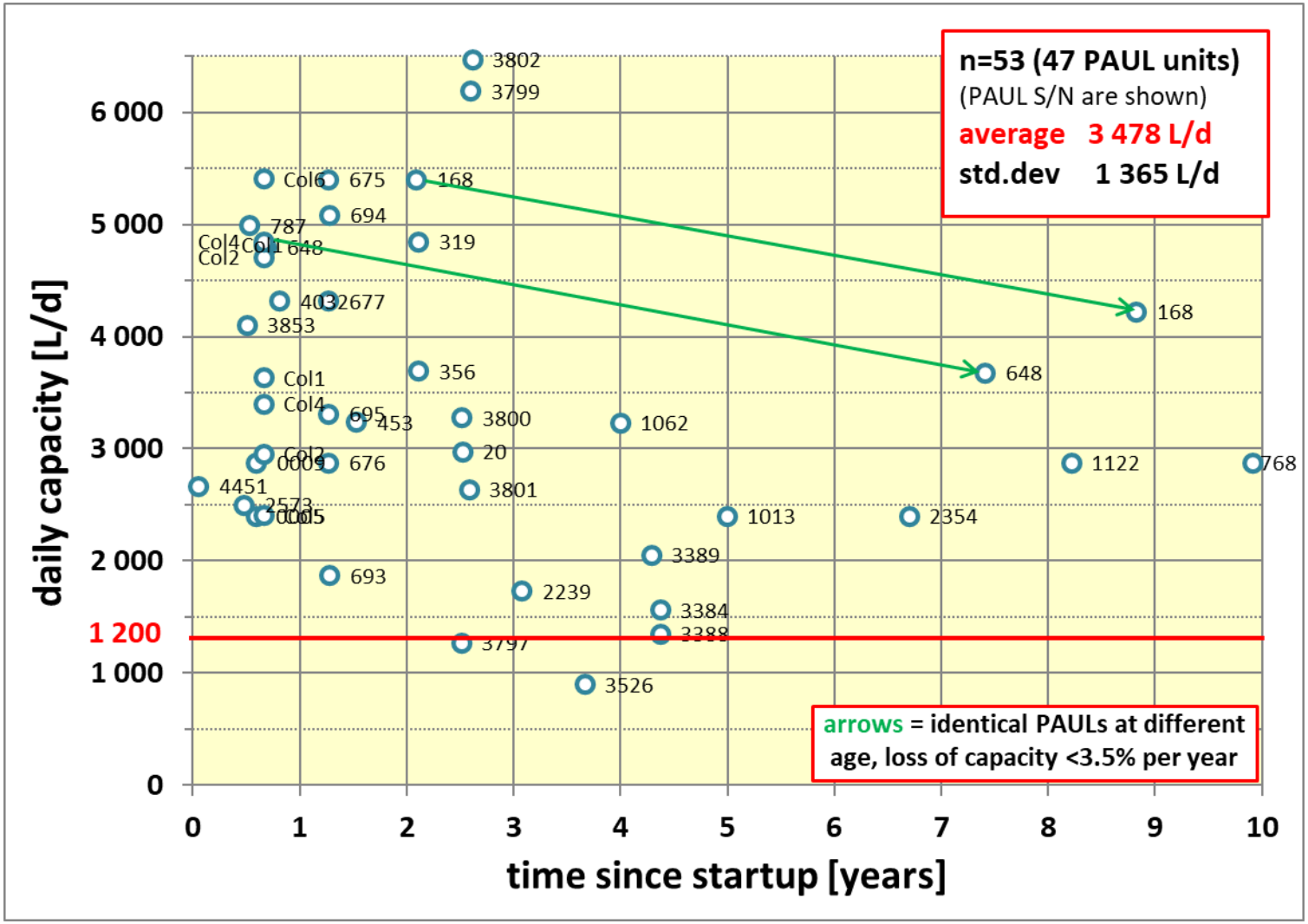
hydraulic capacity



Data source: University of Kassel (sponsored by DBU); private measurement by Mr. Koscheny, Ms. Brandl, Mr. Andres

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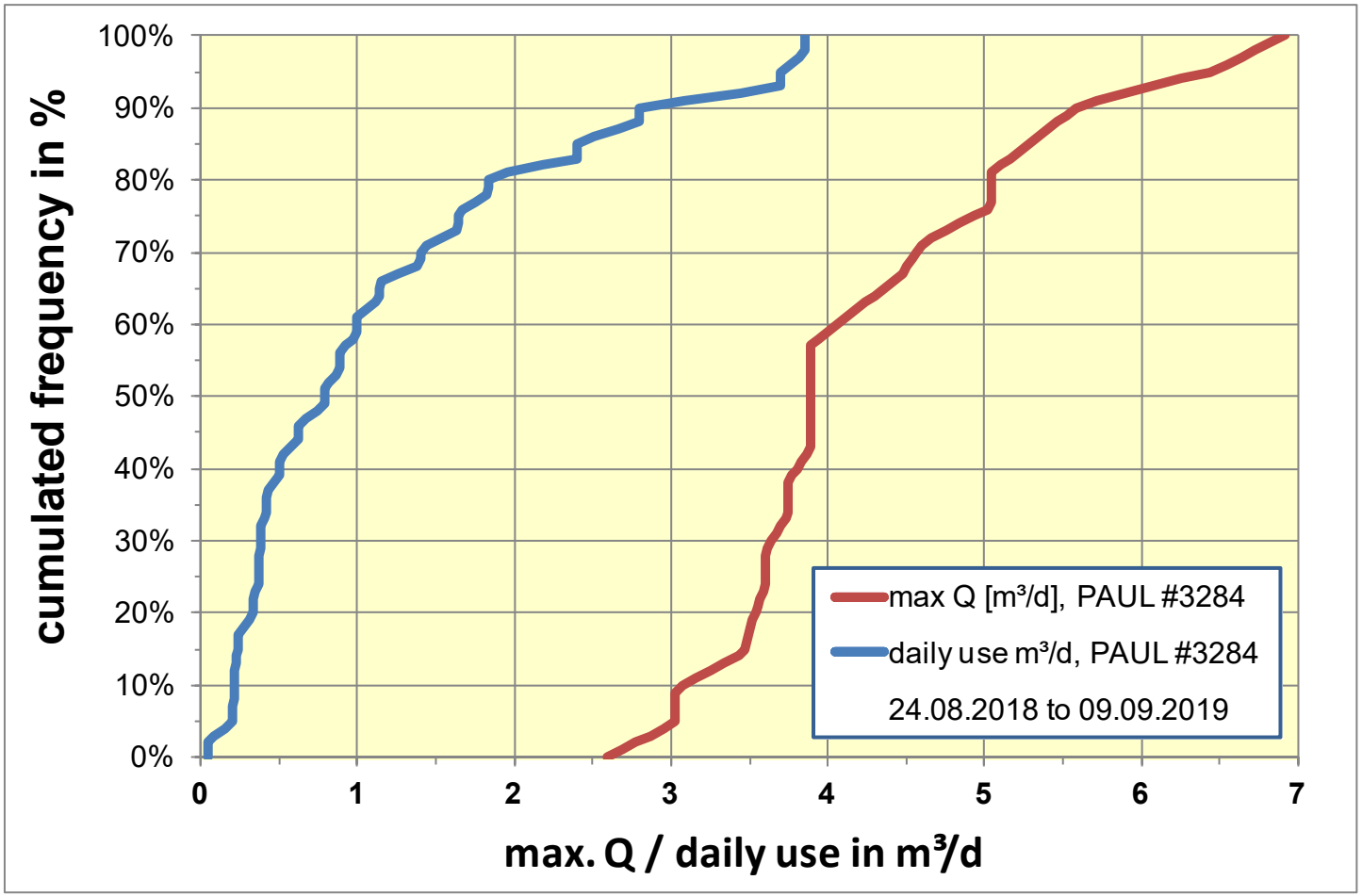
hydraulic capacity and daily usage



Data source: private measurement by Mrs. Duangkaew Tawee (Thailand)

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rainwater ponds as a raw water source

PAUL® can be used with rainwater, groundwater from wells or river water and maybe even other sources. However, the best source for raw water is **rainwater**, most likely from a pond, see examples hereafter, as rainwater usually is free from

- geologic load (e.g. arsenic, other heavy metals)
- industrial pollution
- pollution from farming (e.g. nitrate)

The solids that usually cause the brown color of most ponds (see examples) will be removed perfectly by **PAUL®**

If water is scarce, the only solution seems to be drilling wells. However, this is costly, success is not guaranteed , sometimes the well operation is not sustainable, or drilling may fail in general.

Thus, always also consider the possibility for **rainwater harvesting**. Storage in a cistern, tank or simply a reservoir/lagoon/pond. This usually is cheaper and the quality of the water might be better as outlined above. See examples on the next slides.

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rainwater ponds as a raw water source

Transportation (150 km from Kampala) and work of the excavator was < 2,200 €

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rainwater ponds as a raw water source

PAUL® station under construction
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rainwater ponds as a raw water source

This picture shows the pond in use today. Rainwater is to be used as raw water for **PAUL®** station (background), and cattle directly drink from the pond

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rainwater ponds as a raw water source – **Balkans 2014**

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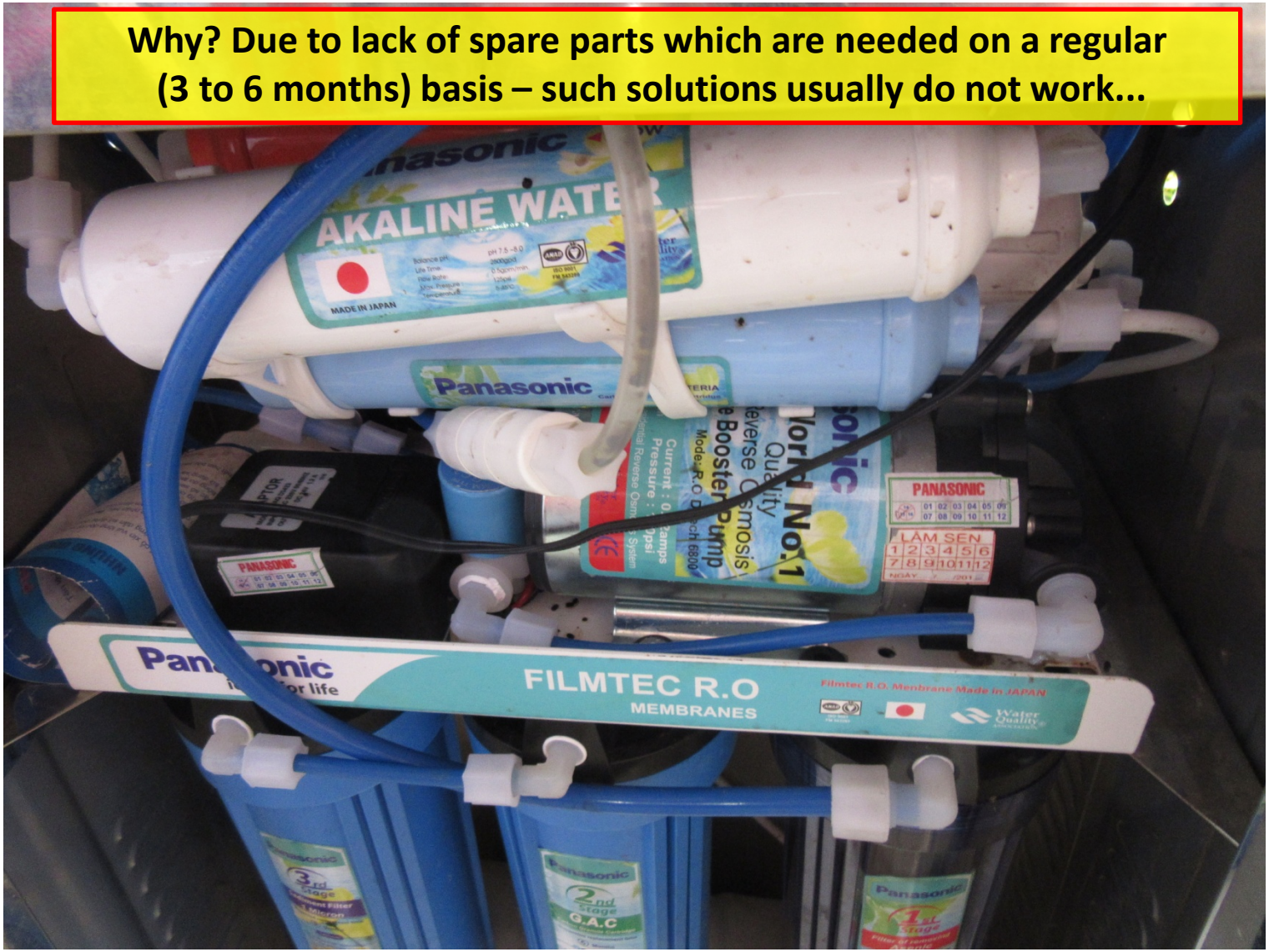
Why? Due to lack of spare parts which are needed on a regular (3 to 6 months) basis – such solutions usually do not work...



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Credits and awards

PAUL® was developed at the

UNIKASSEL VERSITÄT

Research was sponsored by

DBU
Deutsche Bundesstiftung Umwelt
www.dbu.de

PAUL® is assembled at the Kassel Disabled workshop

Sozialgruppe Kassel e.V.

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Selected awards won by PAUL®

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

GreenTec Awards
WINNER 2016
Water & Sewage

AQUA AWARD 2017
AQUANET
BERLIN BRANDENBURG

Lions Clubs International FOUNDATION
2019 Melvin Jones Fellow