Real World Examples from UMC Utrecht (NL)

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The Netherlands
UMC Utrecht

DISCLOSURES

- Research funding from Nextkidney
- Research collaboration with BBraun/ GreenTec, Novaflux and Bilfinger within KitNewCare

Improving sustainability of dialysis

↓ Water
↓ Electric energy
↓ Waste
↓ Transport

Improving sustainability of dialysis

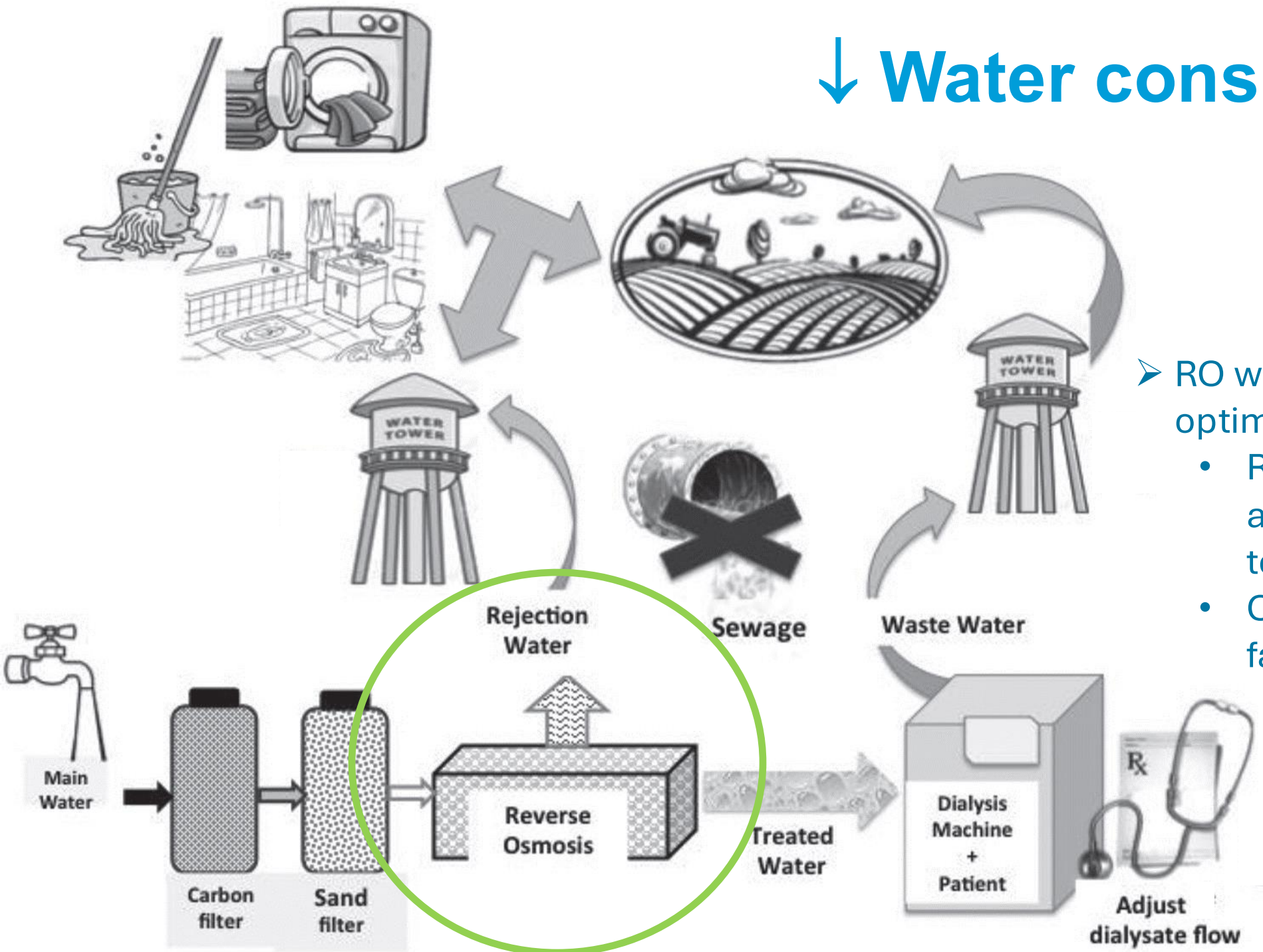
↓ Water

↓ Electric energy

↓ Waste

↓ Transport

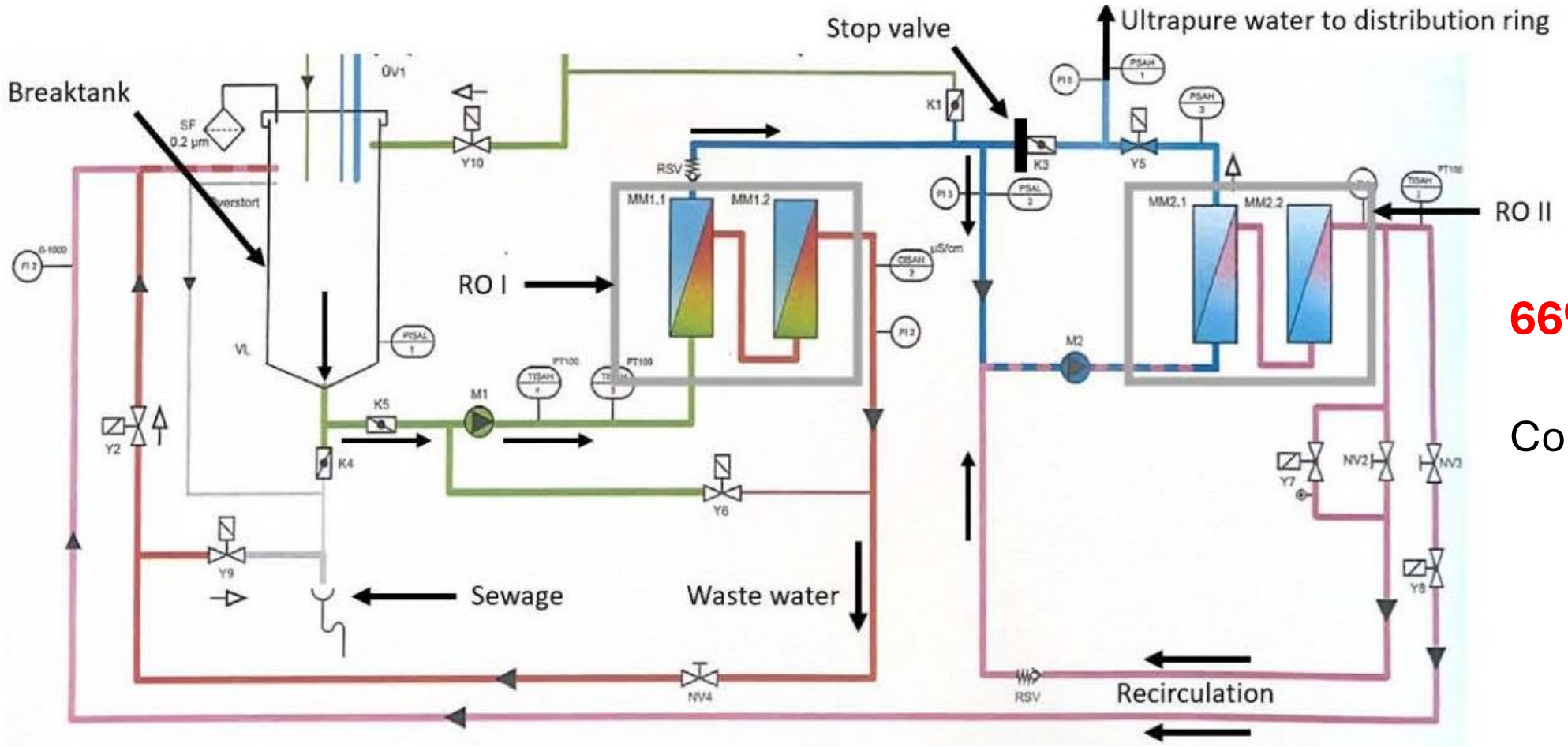
↓ Water consumption



- RO water production optimization:
  - Recycle excess permeate and RO reject water back to feed water
  - Optimize conductivity factor & heat disinfection

DOI: 10.5301/ijao.5000660

Re-inject reject water and excess permeate



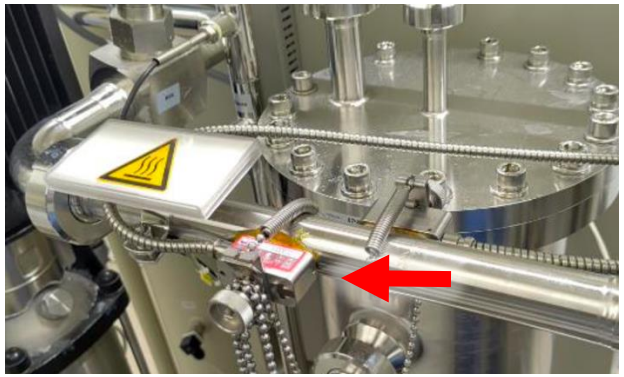
66% recovery

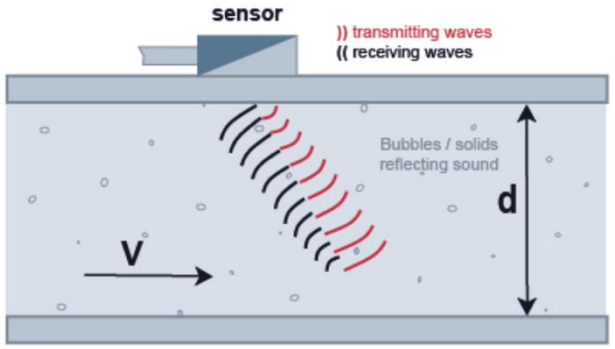
Conductivity factor 3

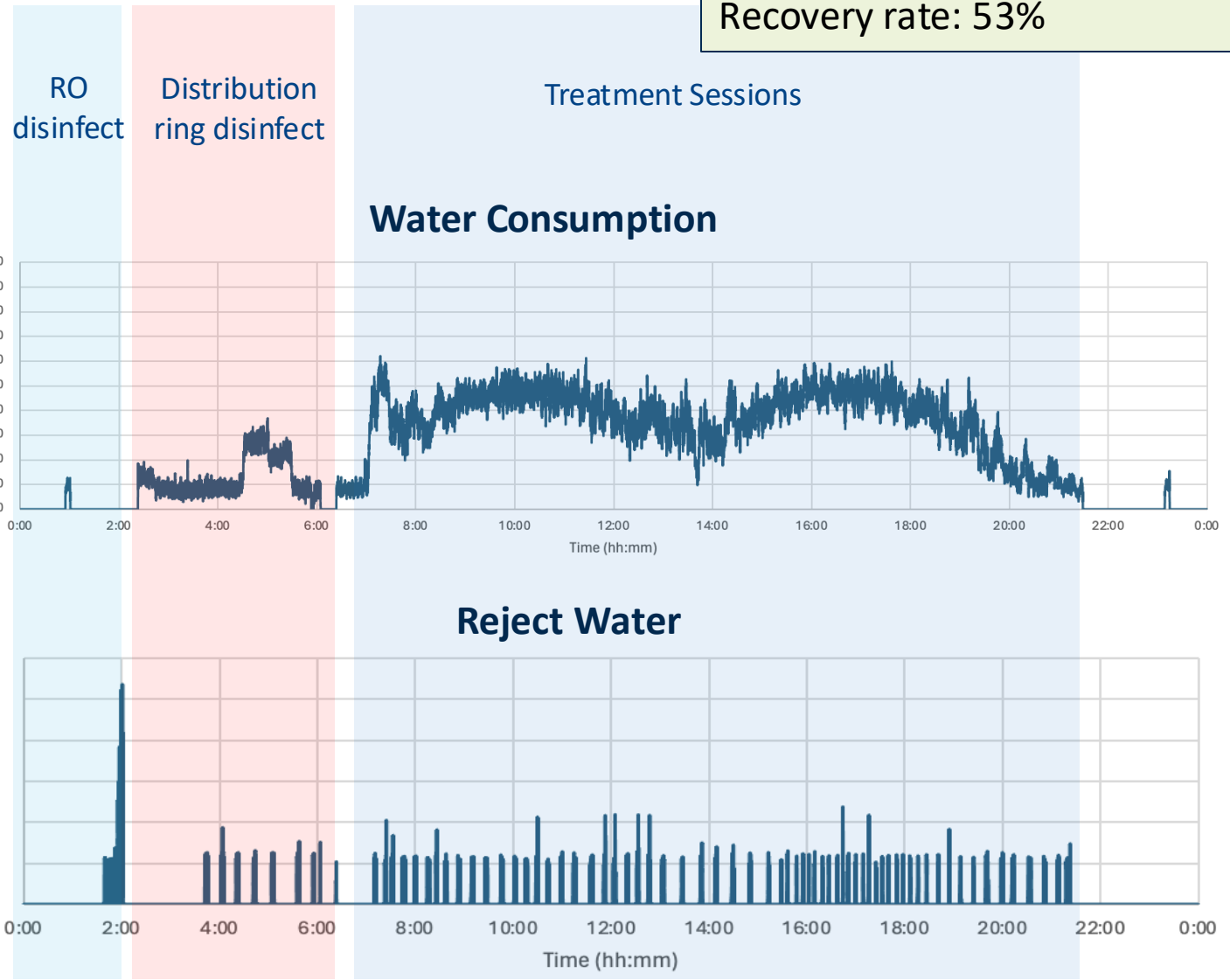
Water measurement

Total water used: 46,167 L/week
On average 346 L/ treatment
Recovery rate: 53%

Flow monitored **non-invasively** with **ultrasonic sensors** attached to pipelines



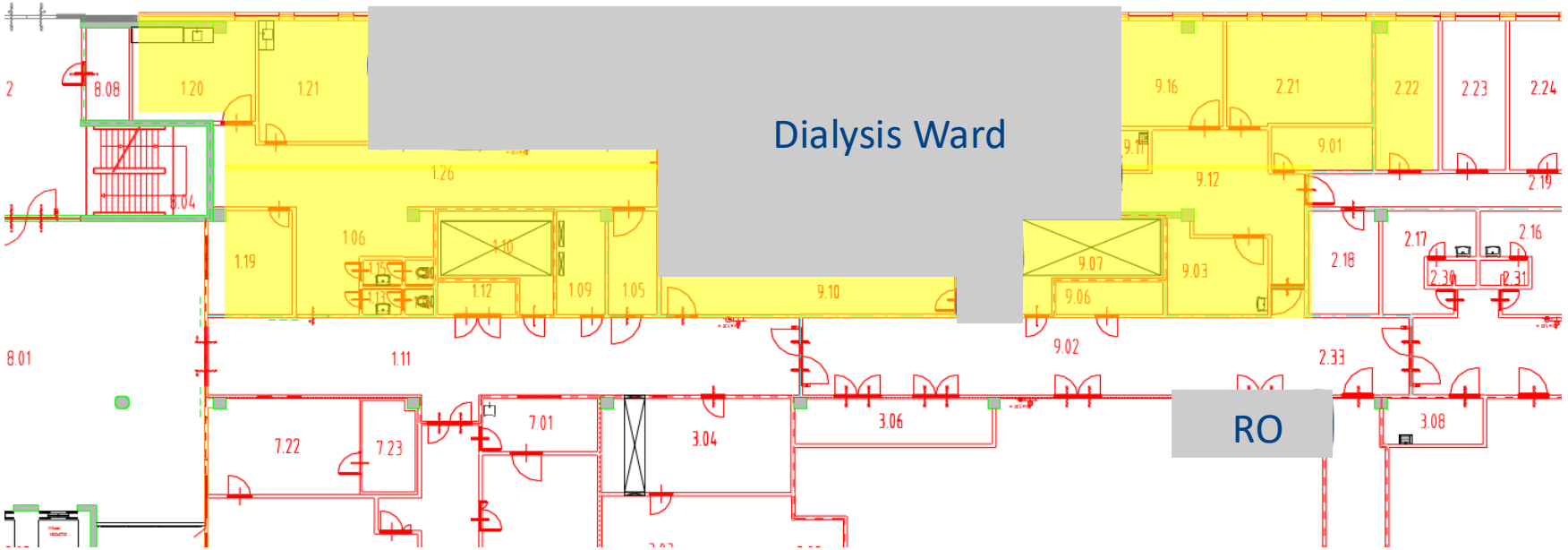




Measurement of energy consumption

Power meters installed to measure energy consumption

Total energy: 1510 kWh/week
On average 11.2 kWh/ treatment
RO system 61%, dialysis treatment 39%



Optimization Plan

1. Increase concentration factor

- Currently ~300 → ~900 µS/cm
- Increase from 3 → 5
- Conductivity <0.5 → ~2 µS/cm (theoretically)
- Theoretical recovery rate 66% → 80%

Target: 1-10 µS/cm (Dutch Guideline on Water Treatment for HD)

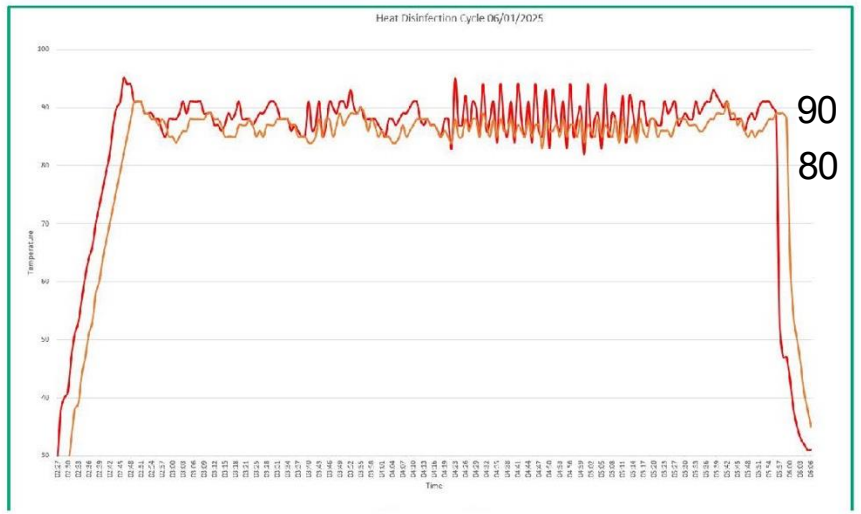
Optimization Plan

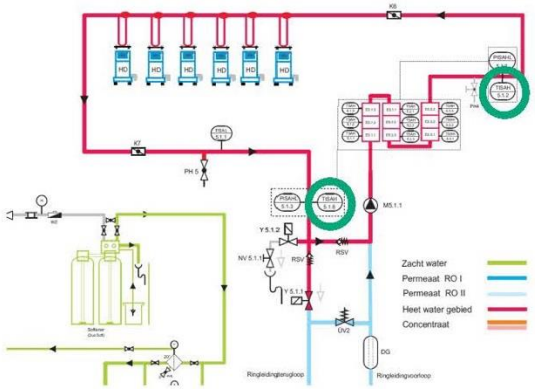
2. Reduce permanent hot disinfection (PHD)

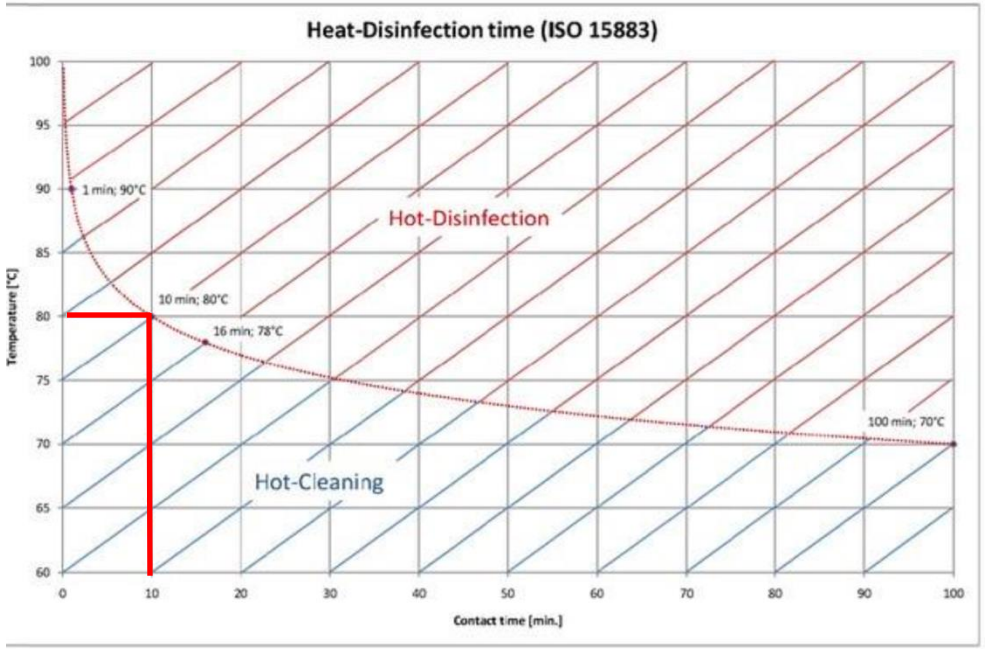
- From 38 min → 15 min
- Theoretical required value 10 min @ 80°C (ISO 15883)

Different phases of the Heat disinfection

- **Heating phase, 30 min.**
- **PHD* phase, 38 min.**
- **Inline phase, 149 min.**
- **Cooling phase, 10 min.**







Optimization Plan

3. Reduced disinfection frequency

- From daily → 3x per week
- Gradual reduction with intermediate validation

NFN-Richtlijn Waterbehandeling voor HD en online HDF, 2020

6.4.1 Desinfectie

Het belangrijkste aspect in het dagelijkse beheer van dialyseapparatuur is desinfectie. Robuuste afdelings-protocollen zijn wenselijk in het bijzonder bij HDF-apparatuur. Vooral apparatuur in bergruimten en acute locaties verdient extra aandacht.

Algemene richtlijnen zijn:

- Desinfectie na iedere behandeling
- Desinfectie iedere 24 uur, tenzij fabrikant langer toelaat bijvoorbeeld 48 of 72 uur.
- Desinfectie na iedere reparatie
- Geïntegreerde hittedesinfectie van dialyseapparatuur via de ringleiding is vooral een effectieve manier om de aanvoerslangen van de apparaten te reinigen.

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Revalidation plan WTS UMC Utrecht, Versie 01

Aquaboss EcoRO Dia II - C 1600 HT, SN2001230021 & Aquaboss Hot Rinse Smart 30, SN1100300117

Date	Changes made	Control measures	Sample location	Microbiological sample*	Endotoxin sample*	Remarks
Start	-	-	-	-	-	See attachment 1, overview of actual switching times
Step 1, Start date	Adjusting the PHD cycle time of the ring heat disinfection. Minus 15 minutes, machines must start 15 minute earlier.	-	-	-	-	See attachment 2
Start date + 1 weeks	-	First permeate samples after step 1, use regular weekly sample	End of the ring	✓	✓	-
Start date + 2 weeks		Second permeate sample after step 1, use regular weekly sample	End of the ring	✓	✓	After negative result of both samples, release for the next step, Step 2
Step 2, Start date + 3 weeks	Move Hot-RO disinfection to Monday & Skip the Heat disinfection cycle of the ring including dialysis machines on Sunday	-	-	-	-	See attachment 3
Start date + 4 weeks	-	First permeate samples after step 2, use regular weekly sample	End of the ring	✓	✓	-
Start date + 5 weeks		Second permeate sample after step 2, use regular weekly sample	End of the ring	✓	✓	After negative result of both samples, release for the next step, Step 3
Step 3, Start date + 6 weeks	Skip the Heat disinfection cycle of the ring including dialysis machines on Tuesday	-	-	-	-	See attachment 4
Start date + 7 weeks	-	First permeate samples after step 3, use regular weekly sample	End of the ring	✓	✓	-
Start date + 8 weeks		Second permeate sample after step 3, use regular weekly sample	End of the ring	✓	✓	After negative result of both samples, release for the next step, Step 4
Step 4, Start date + 9 weeks	Skip the Heat disinfection cycle of the ring including dialysis machines on Thursday	-	-	-	-	See attachment 5
Start date + 10 weeks	-	First permeate samples after step 4, use regular weekly sample	End of the ring	✓	✓	-
Start date + 11 weeks		Second permeate sample after step 4, use regular weekly sample	End of the ring	✓	✓	After negative result of both samples, release for the next step, Step 5
Step 5, Start date + 12 weeks	Skip the Heat disinfection cycle of the ring including dialysis machines on Saturday	-	-	-	-	See attachment 6

Optimization Plan

4. Reduce permeate production

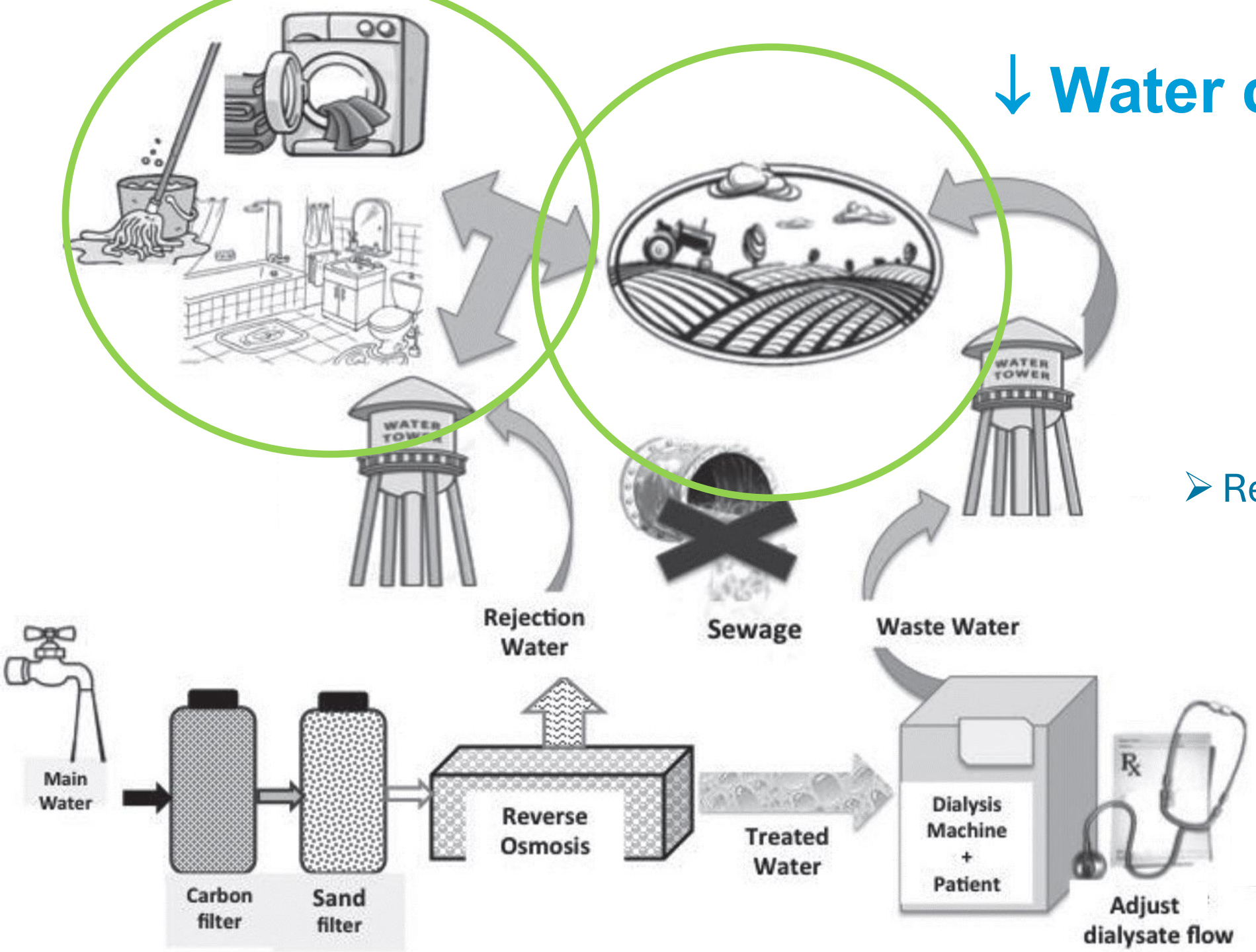
>1600 L/h!

800 L/h
17 HD machines

SMART DIALYSIS®

GREENTEC DIALYSIS
NO TIME TO WASTE

↓ Water consumption



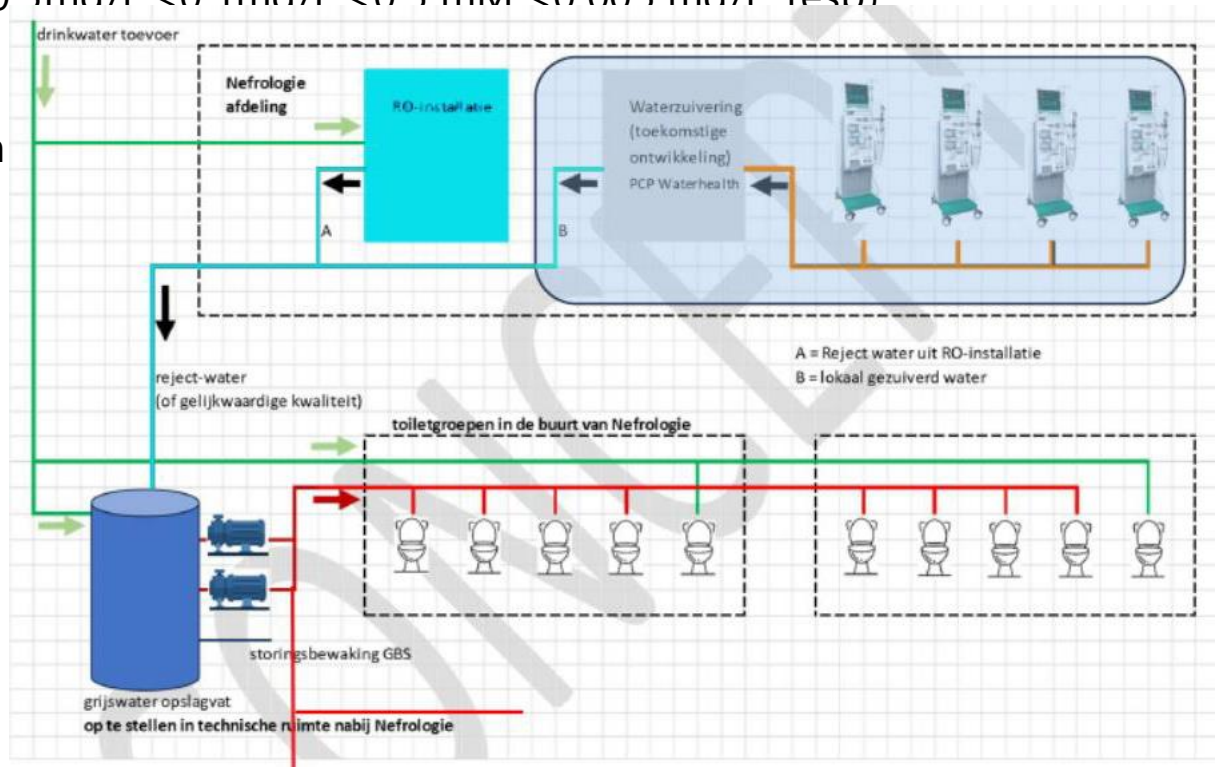
- Reuse RO reject water

DOI: 10.5301/ijao.5000660

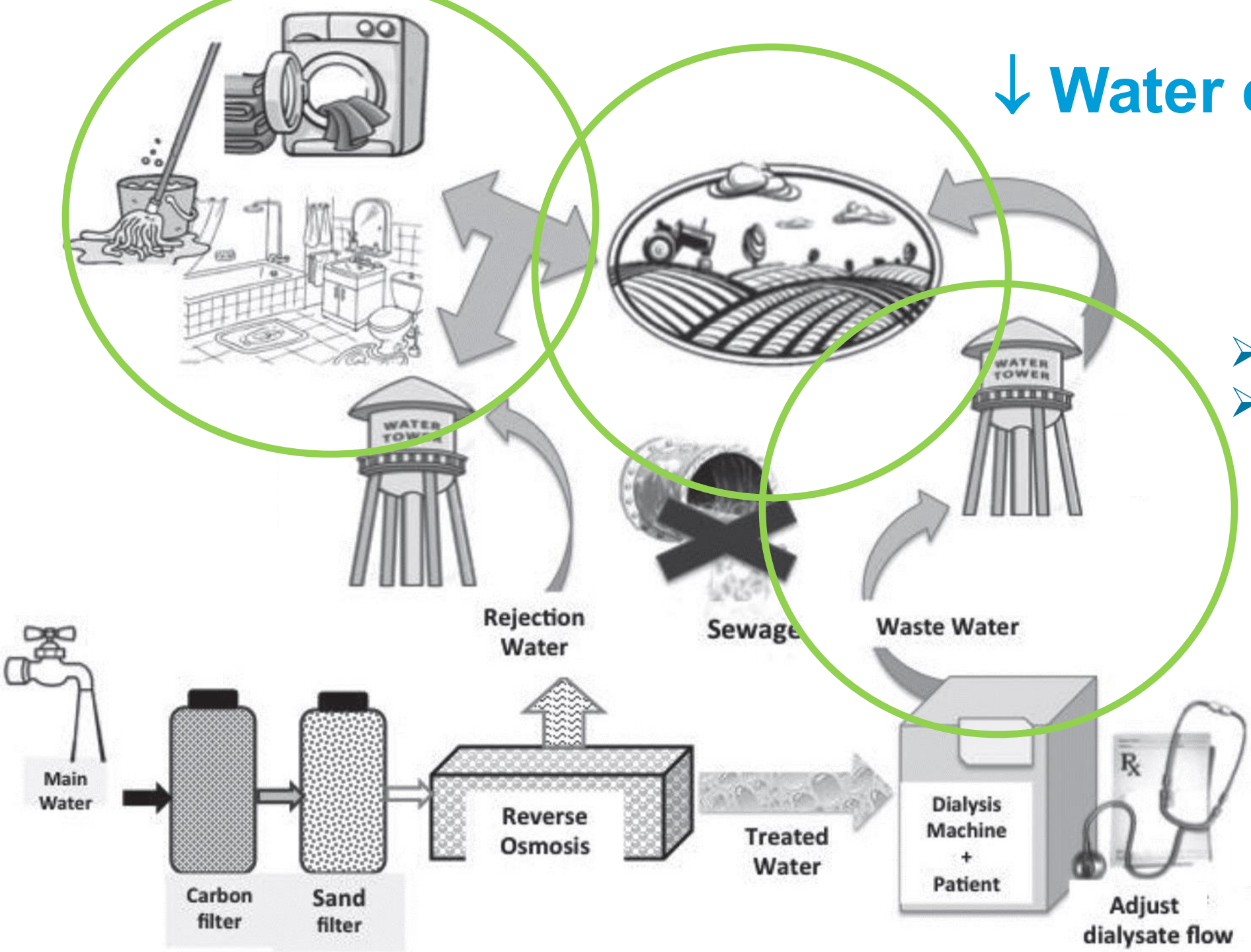
Measurement reject water

- 22 m3/ week
- Sample analysis:
  - Conductivity <1500 µS/cm, osmolality 15 mOsmol/kg
  - Total dissolved solids: 470 mg/L
  - No calcium, magnesium, silicate or manganese (<0.5mg/L ;<0.1mg/L ;<0.5 mM;<0.005 mg/L resp)
  - [Na^+] 7.1 mM, [Cl^-] 2.2 mM
  - pH 7.5
  - Nitrate 3.9 mg/L = 63 µM, no nitrite or ammonium
  - Dissolved organic carbon 1.2 mg/L

Reuse possible for multiple purposes



↓ Water consumption



- Reuse spent dialysate
- Removal of residues and nutrients (nitrogen, phosphorus)

DOI: 10.5301/ijao.5000660

Large pill burden → spent dialysate as medication hotspot?

Group	Pharmaceutical	Priority	Targeted analytes	Reported metabolites
Sterilization agent	Citric acid	Low	Intact	-
Anticoagulant	Dalteparin	Low	Intact	
Iron replacement	Ferric derisomaltose	Low	intact	
Erythropoiesis stimulant	Darbepoetin alfa	Medium	intact	
Vitamin D analogue	Alfacidol	High	Metabolite	Calcitriol
Diuretic	Furosemide	High	Intact and metabolites	Glucuronide conjugates
Diuretic	Bumetanide	Medium	Intact and metabolites	Desbutyl bumetanide
Diuretic	Spironolactone	High	Intact and metabolites	Canrenone, 7α-thiomethylspironolactone, and 6β-hydroxy-7α-thiomethylspironolactone
ACE inhibitor	Fosinopril	Low	Intact and metabolite (faeces)	Fosinoprilat
ACE inhibitor	Lisinopril	Low	Intact	Unchanged
ACE inhibitor	Enalapril	Medium	Intact and metabolite	Enalaprilat
ACE inhibitor	Perindopril	Medium	Intact and metabolite	Perindoprilat
Angiotensin receptor blocker	Losartan	Low	Intact and metabolite	EXP3174 (Losartan carboxylic acid)
Angiotensin receptor blocker	Irbesartan	Low	Intact	Glucuronide conjugates
Angiotensin receptor blocker	Valsartan	Low	Intact and metabolites	Unchanged
Beta blocker	Metoprolol	High	Metabolites	α-Hydroxymetoprolol and O-desmethylmetoprolol
Beta blocker	Bisoprolol	High	Intact	Glucuronide conjugates
Beta blocker	Carvedilol	Low	Metabolites	Carvedilol O-sulfate, 4'-hydroxyphenyl carvedilol and 3-hydroxycarvedilol
Calcium antagonist	Amlodipine	Low	Intact and mainly metabolites	Different minor metabolites
Calcium antagonist	Barnidipine	Medium	Metabolites	Barnidipine Pyridine Metabolite
Proton pump inhibitor	Pantoprazole	Medium	Mainly metabolites	Demethylated Pantoprazole (Sulfide and Sulfone)
Proton pump inhibitor	Omeprazole	Medium	Mainly metabolites	Hydroxyomeprazole and omeprazole sulfone
Proton pump inhibitor	Esomeprazole	Medium	Mainly metabolites	Hydroxyesomeprazole and esomeprazole sulfone
Proton pump inhibitor	Rabeprazole	Medium	Mainly metabolites	Rabeprazole thioether
Statin	Atorvastatin	Low	Intact and metabolites	Ortho- and para-hydroxyatorvastatin
Statin	Rosuvastatin	Low	Intact	N-desmethyl rosuvastatin
Statin	Simvastatin	Low	Intact and metabolites	Simvastatin acid (active form)
Statin	Pravastatin	Low	Intact and metabolites	3α-Hydroxypravastatin
Corticosteroid	Prednisolone	High	Intact and phase 2 conjugates	Prednisolone 21-sulfate and 6β-hydroxy-prednisolone
Analgesic	Paracetamol	Low	Intact and phase 2 conjugates	Glucuronide conjugates
Anticoagulant	Acenocoumarol	Medium	Intact and metabolites	7-Hydroxyacenocoumarol and 3'-Hydroxyacenocoumarol
Anticoagulant	Phenprocoumon	Medium	Intact and metabolites	7-Hydroxyphencoumarol and 3'-Hydroxyphencoumarol

Regeneration of dialysate

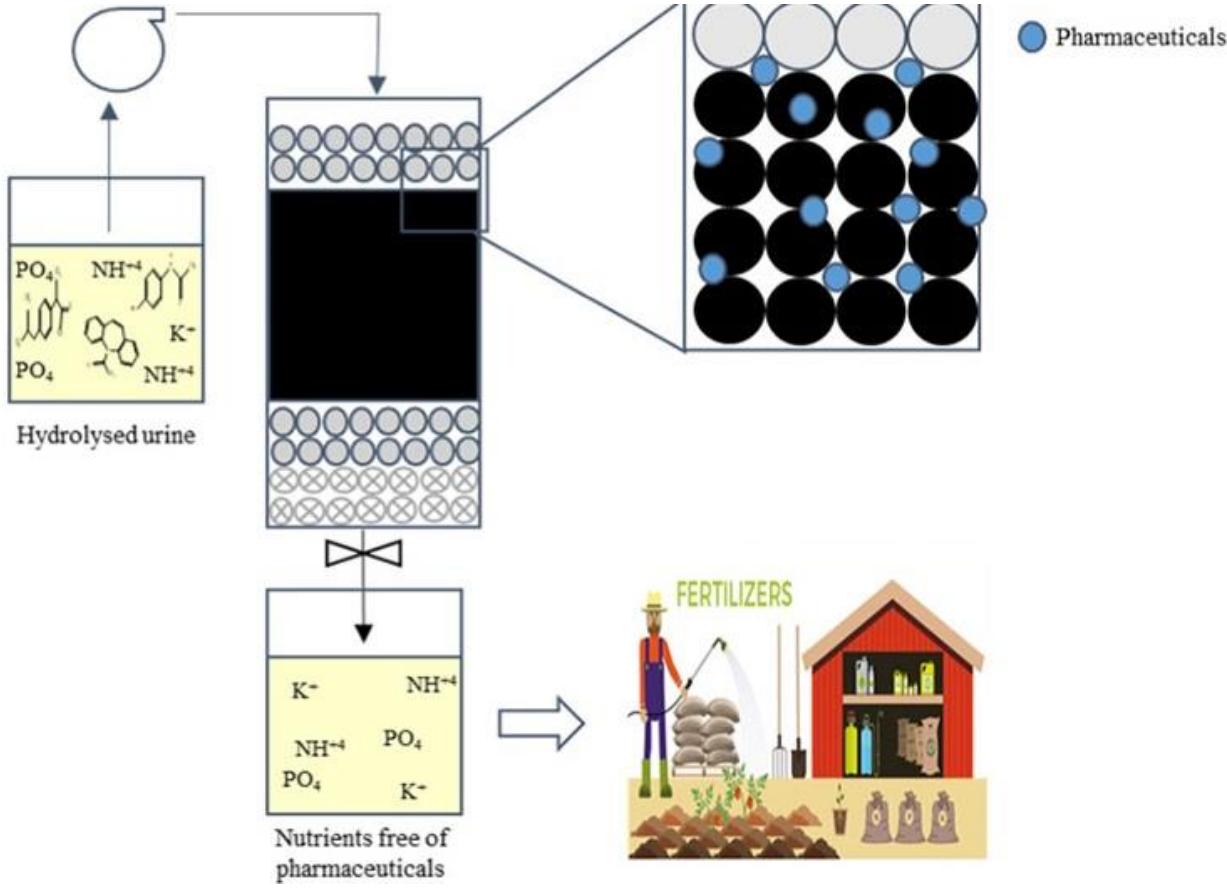
Nephrology Dialysis Transplantation

SP674 **THE USE OF RDT DIALYSATE AS FERTALIZER**

Athanasios Diamandopoulos[1,2], Antonios Diamandopoulos[3], Zoi Tegou[4]

[1]Internal Medicine, EKPA, Patras, Greece, [2]Board, Louros Foundation for the History of Medicine, Athens, Greece, [3]Management, Orangia Eco-hosting Farm, Gastouni, Greece and [4]Nephrology Ward, St. Andrew State Hospital, Patras, Greece

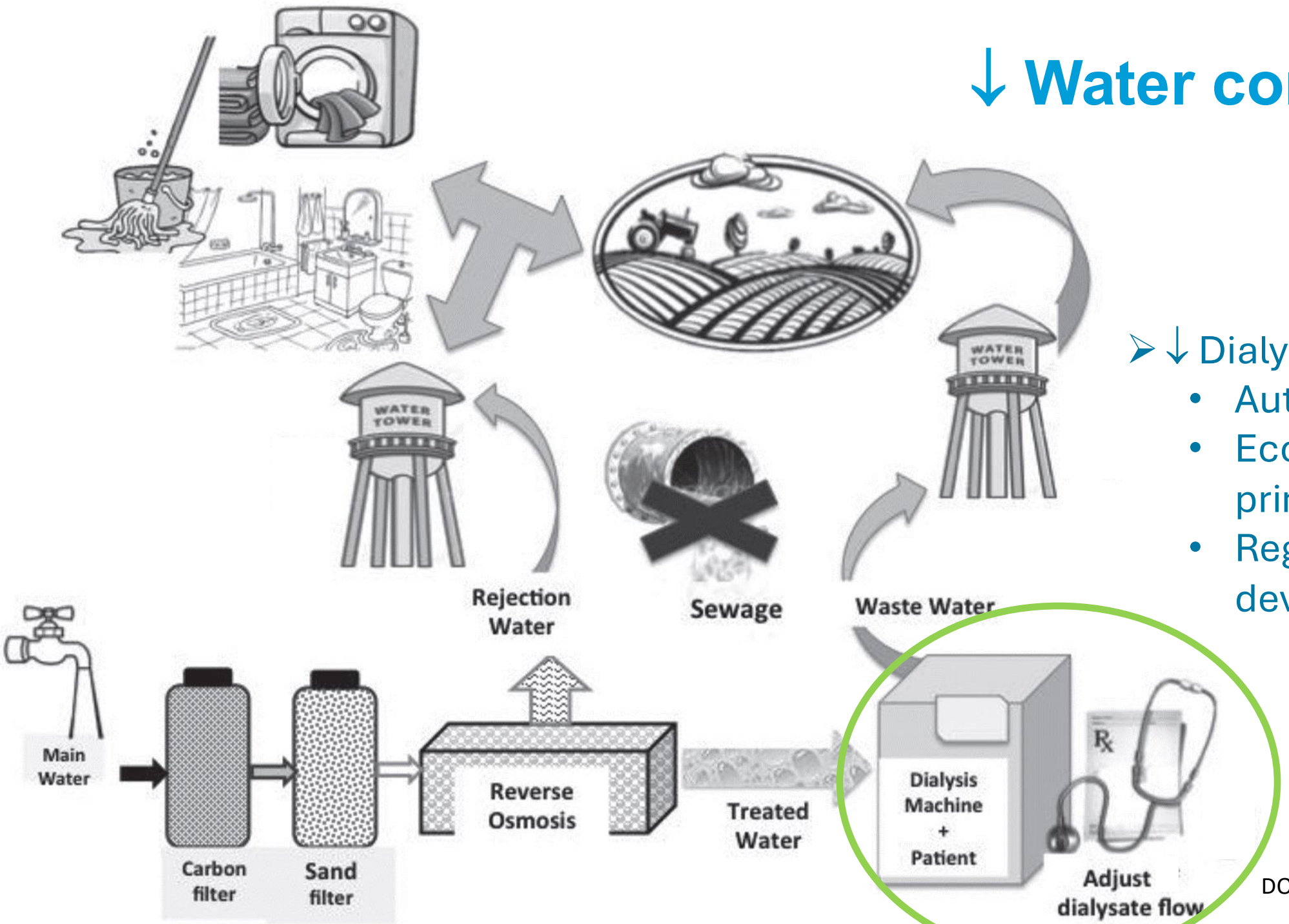
https://doi.org/10.1093/ndt/gfy104.SP674



- Advanced sorbent technologies
- Advanced oxidation processes
- (Nanofiltration) membrane technologies
- Electrodeionization (EDI) for desalination
- Nitrogen and phosphorus recovery (and use as fertilizer) through struvite crystallization by adding magnesium sulfate (DOI: 10.1007/s40620-024-01989-6)

BiLFINGER

↓ Water consumption



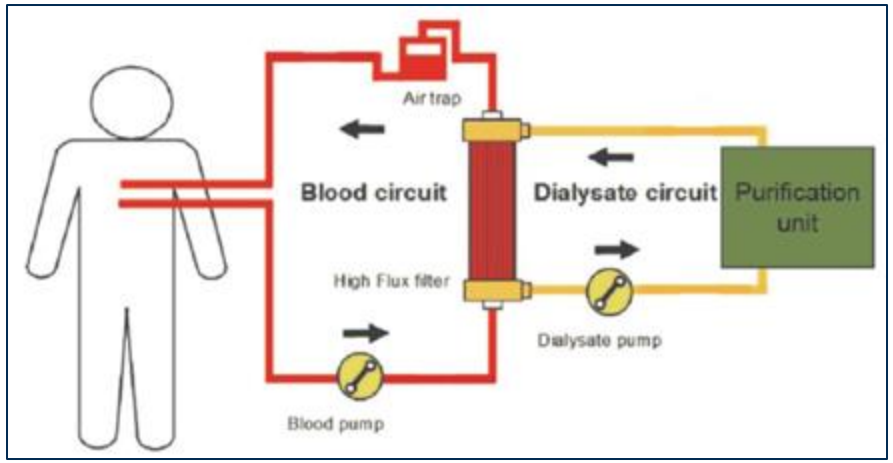
- ↓ Dialysate
  - Autoflow
  - Ecoflow/ turn off after priming
  - Regenerative dialysis devices

DOI: 10.5301/ijao.5000660

Regenerative dialysis devices

- Per treatment **~4.5L dialysate**
- **Pivotal trial 2025**

CORDIAL



LCA

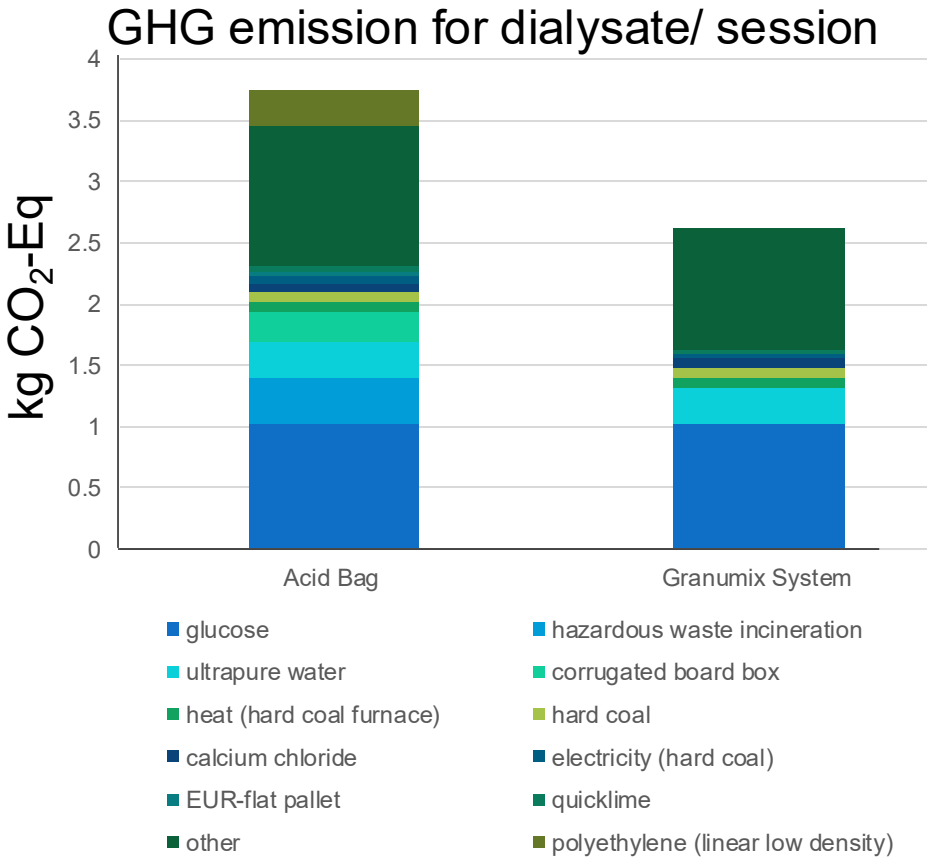
Improving sustainability of dialysis

↓ Water
↓ Energy
↓ **Waste**
↓ Transport

↓ Waste

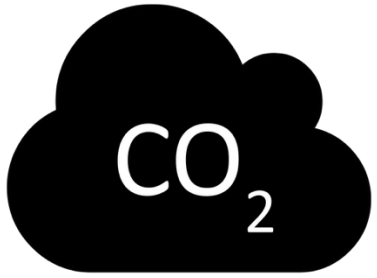
- Central acid delivery using dry concentrate powder
  - Ecomix (BBraun)
  - Granumix (Fresenius)

100% reusable polyester containers

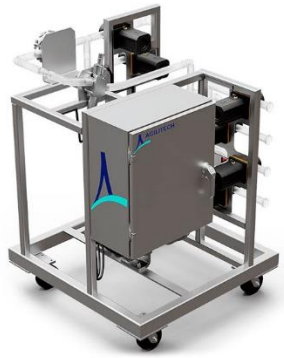


- Alternative for bicarbonate cartridges?

BiLFINGER



CO_2 blanketing



In-line dilution

Refilling cartridge on-site

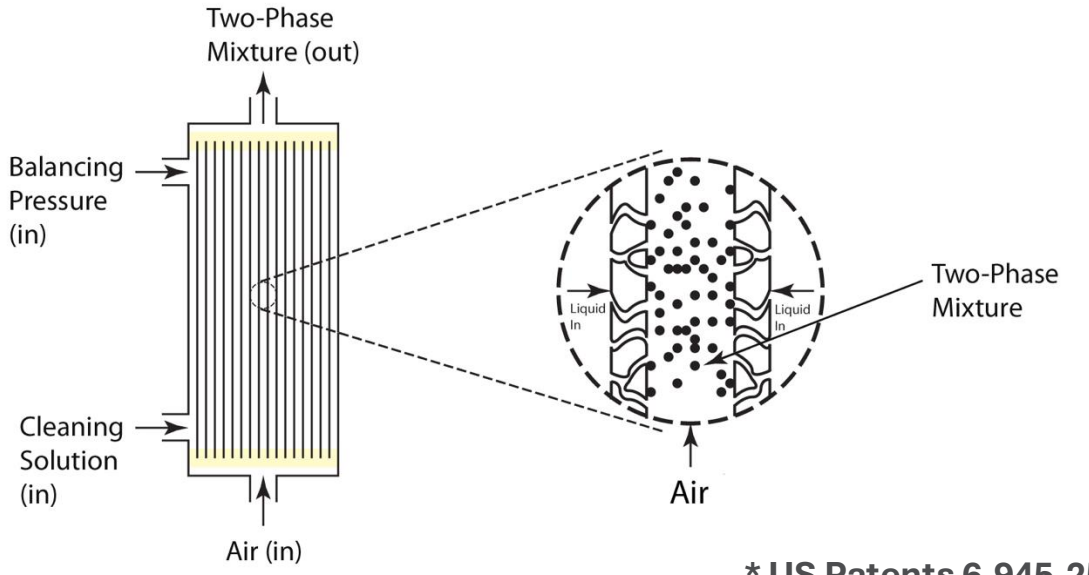
-

Reuse of dialyzers

ClearFlux Machine
Source: https://www.novaflux.com/clea

In Situ Two-Phase-Flow in Fiber Lumens

Water consumption per cycle: 10L
Last step peracetic acid



*** US Patents 6,945,257 & 7,367,346**

Timeline

Medical Technology & Clinical Physics cluster (MTKF)

- ISO 13485
- IEC 60601
- EMC compliance

MsC → PhD

Jan 2025 | June 2025 | 2026 | 2027 | 2028

Investigation → **Conceptual Design** → **Development** → **Implementation**

Feb: Transfer of ClearFlux

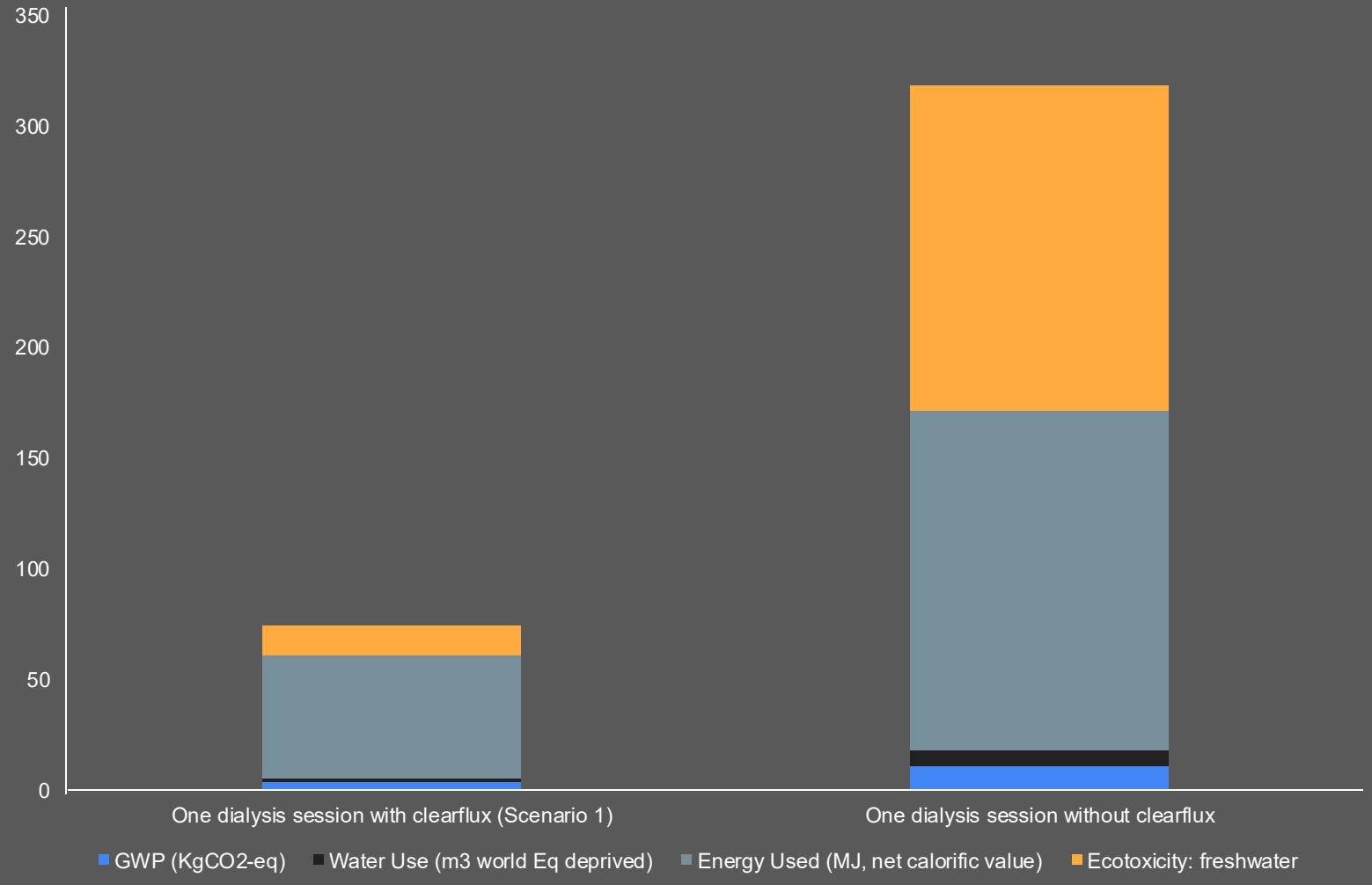
- **Feasibility Study** (LCA)
- **EU Regulatory Gaps** (MDR article 17(3): reprocessing of single-use devices)
- **Laboratory testing** (single-use, hemodiafiltration dialyzers)
- **Stakeholder Inputs** (mfg, clinical users, patients)
- **Clinical Fieldwork**
- **Improve Design** (aim to reduce cost & risks, increase capacity)
- **Prototyping**
- **Engineering Testing**
- **Clinical Testing**

LCA

Dr. Hafsah Hachad
Physician/ PhD candidate

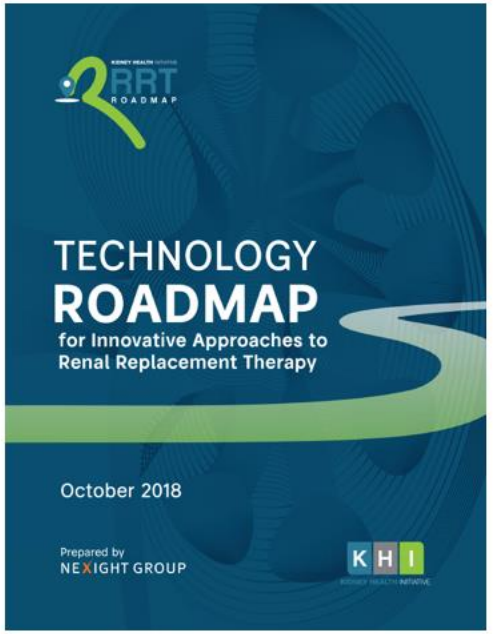
Abass Fehintola
PhD student

Impact assessment Result of One dialysis session with ClearFlux (Scenario 1) and without ClearFlux

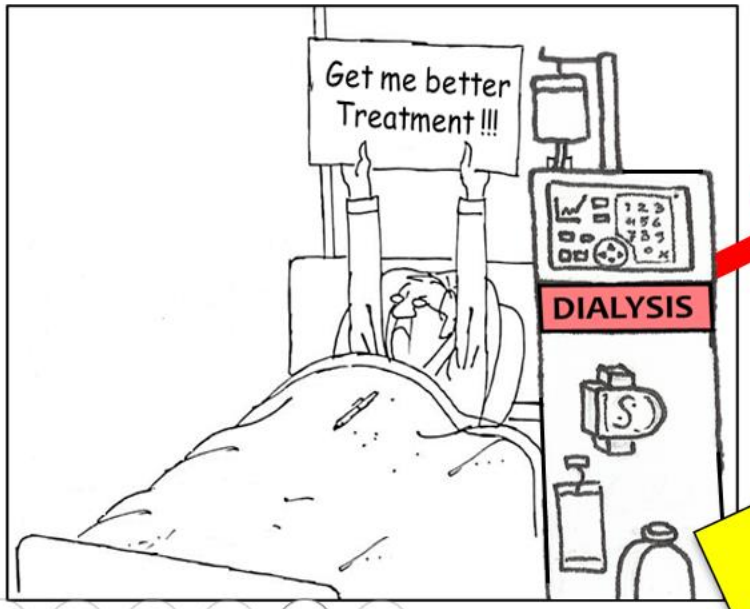


- **Global Warming Potential (GWP, kgCO2-eq): ↓69.3%**
- **Water Use (m³ world Eq deprived): ↓ 77.8%**
- **Energy Used (MJ, net calorific value): ↓ 63.6%** savings
- **Ecotoxicity: Freshwater ↓ 91.1**

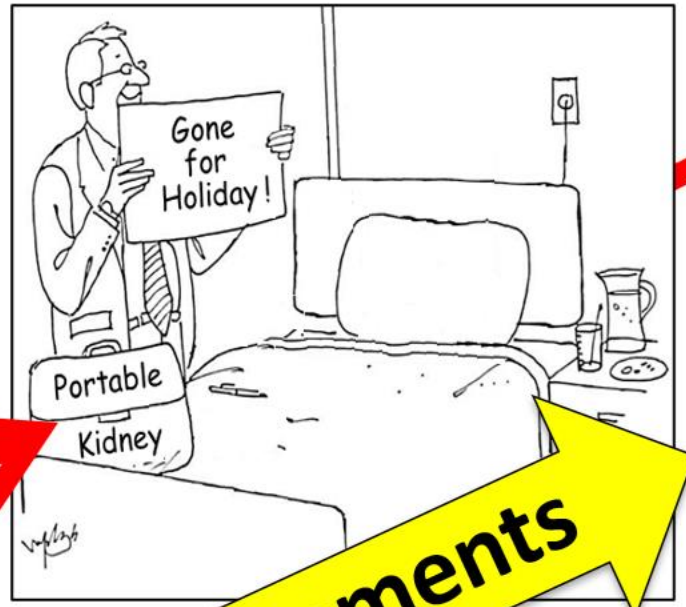
Roadmap to sustainable RRT



Stuck in a chair/bed

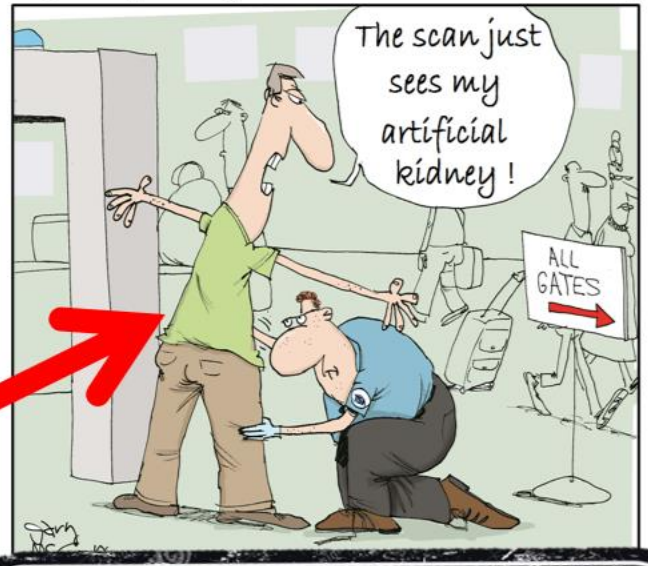


Able to travel



improvements

24/7 (bio)artificial kidney



QUALITY OF LIFE

ECO FRIENDLY

COST-EFFECTIVE

Improving sustainability of dialysis

↓ Water

↓ Energy

↓ **Waste**

↓ Transport

↓ Transport

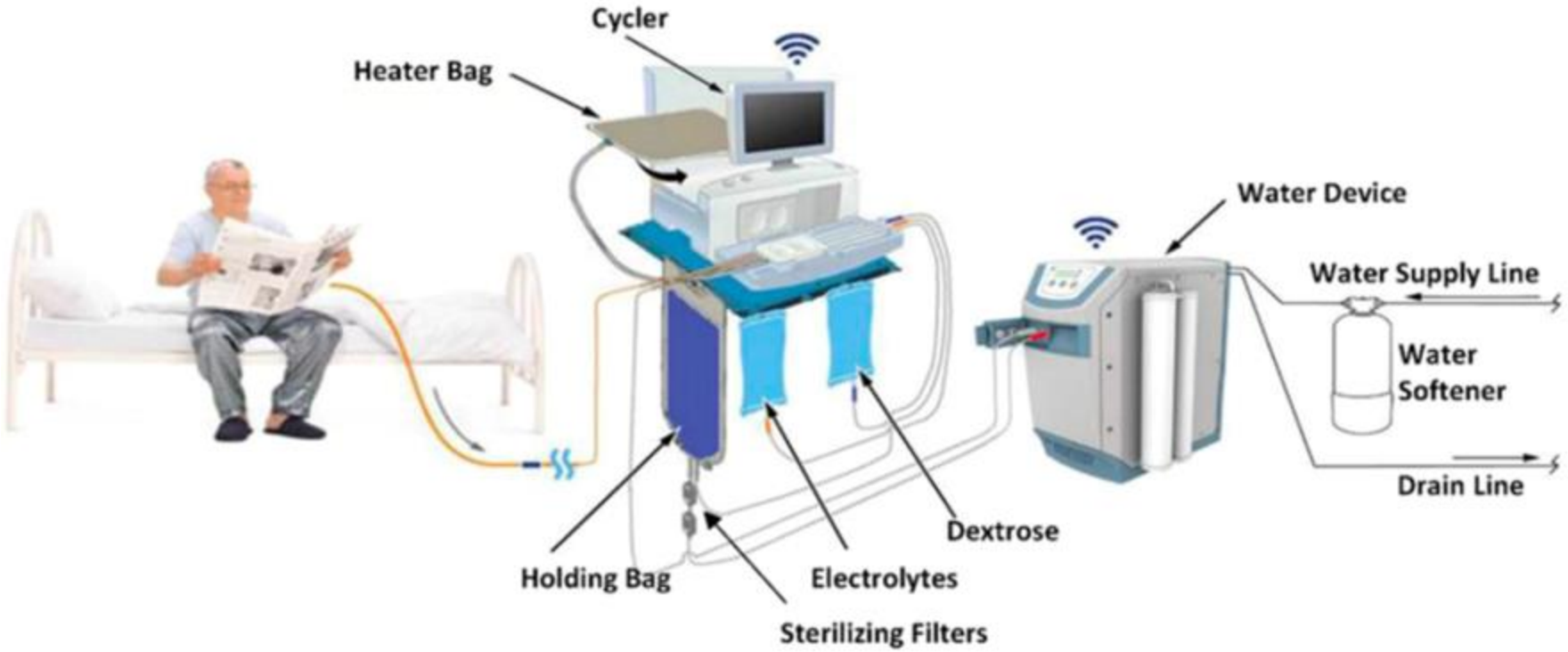
- (Non-assisted) home dialysis
- Microclinics close to patient’s home

DIANET

Centrifuge at home

Nextkidney

In home peritoneal dialysate generation



https://doi.org/10.1016/j.ekir.2024.03.010