Removal of pharmaceuticals out of WWTP effluent in The Netherlands

Maarten Nederlof

Waterschap Rijn en IJssel

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Outline

- Introduction
- Implementation program (proven technologies)
- Innovation program (promising technologies)
- Status quo (2024)
- Future perspective

About ten years ago: recognition of the problem

- Improved laboratory techniques (concentrations in µg/l, even ng/l)
- First scientific report (national Institute for Public Health and the Environment) in 2016 (second in 2020)
- Broad awareness in water sector and public
- Dutch Chain Approach, >2016 (health care and water sector!)
- Lot of questions left

  Where is it a problem (all the WWTP's?)

  What are standards,
  Guidelines for pharmaceuticals?

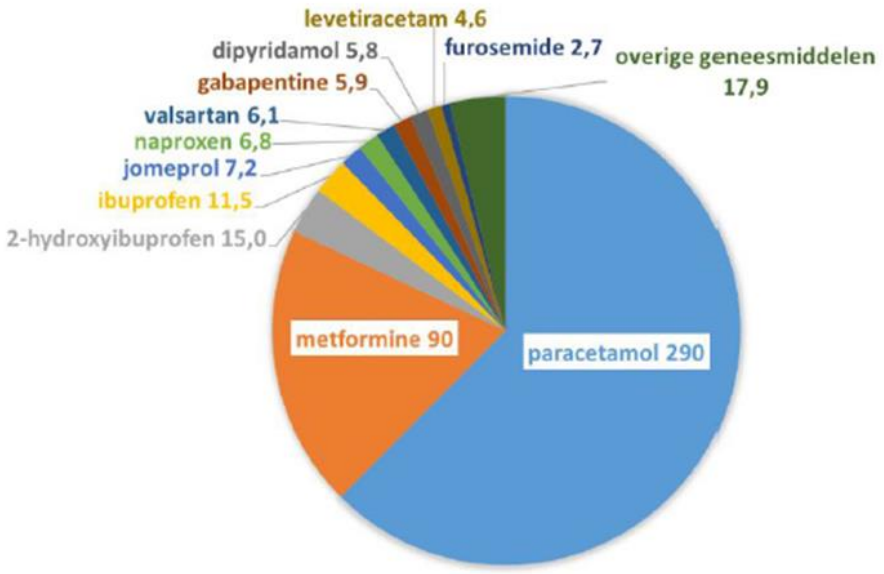
  Source approach or end of pipe?

  What technologies are available?
  When (<2027 WFD, <2045 UWWD)?

  (Investment) Costs?

- >2019 Technology Program

Presence of pharmaceuticals in urban waste water

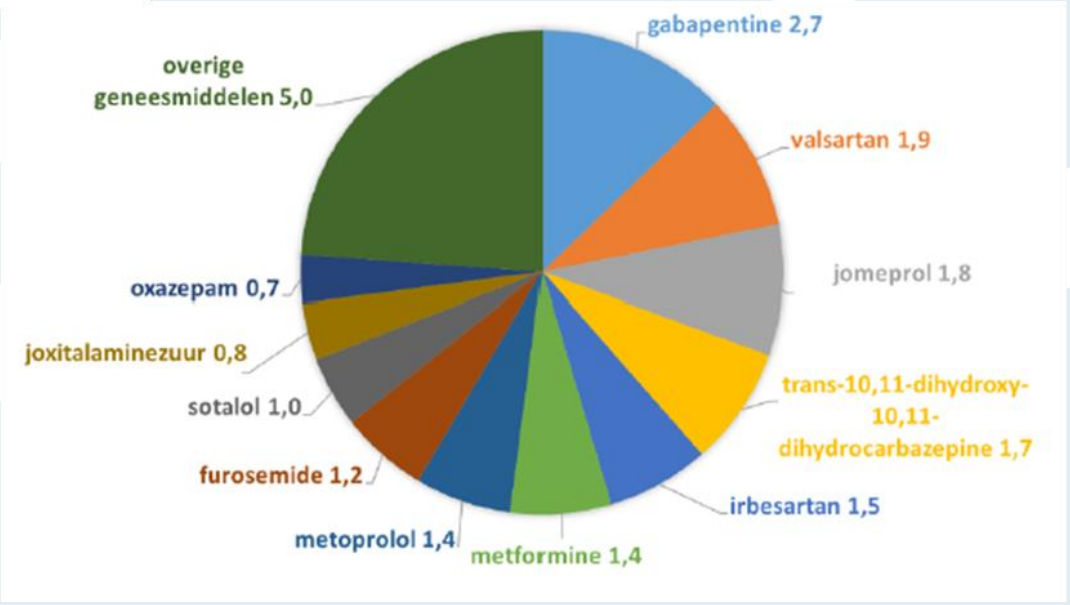


IN: 0,46 mg per liter

paracetamol en metformine bepalen driekwart vracht

UIT: 0,04 mg per liter

breed scala



Presence of Pharmaceuticals in water (examples, µg/l)

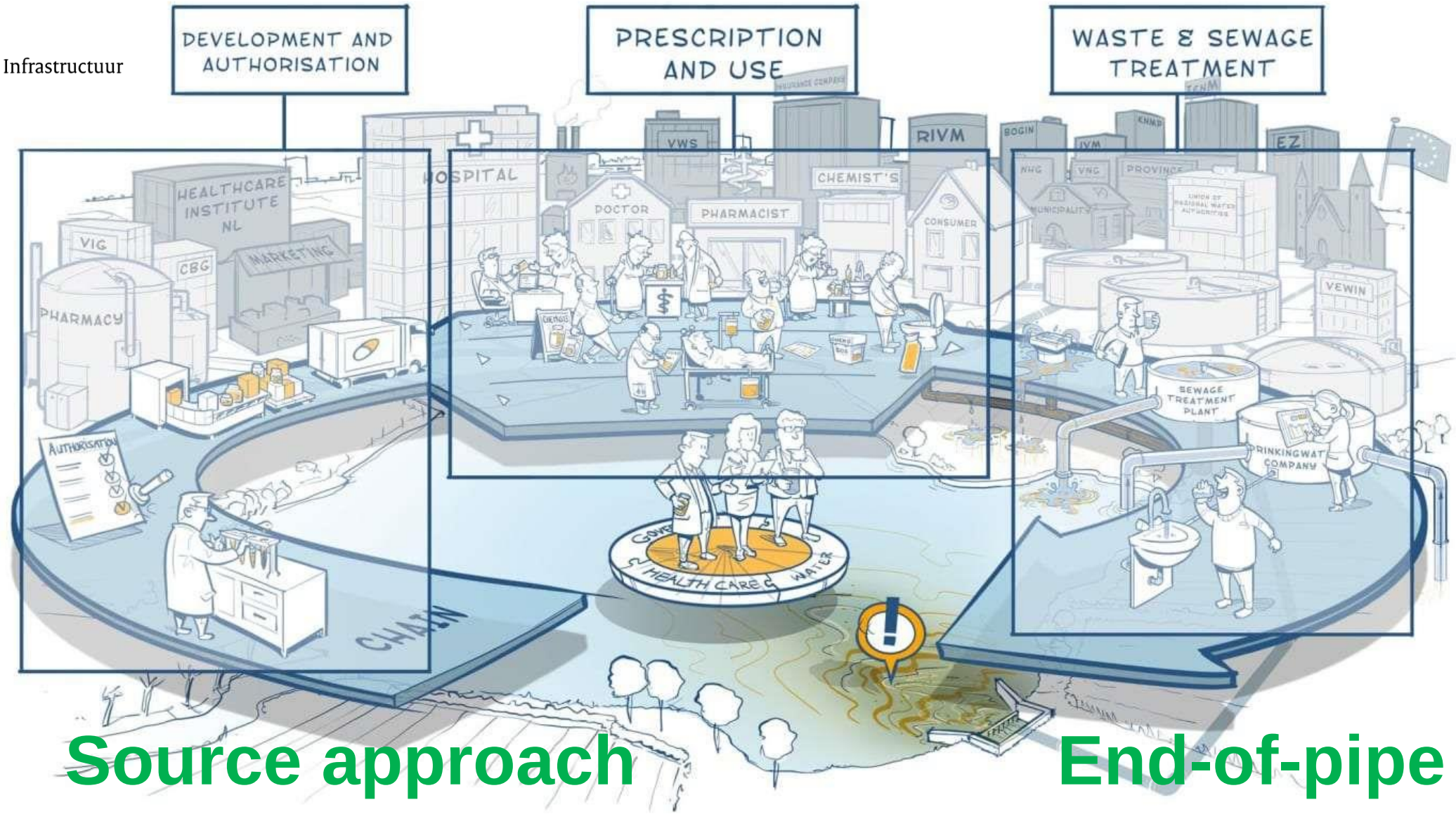
Pharmaceutical	Diclofenac	Metformine	Clarithromycine
Waste water	0,33-0,59	64-100	0,1-0,7
WWTP effluent	0,19-0,40	0,4-1,7	0,04-0,19
Surface water up	0,013-0,076	0,25-0,68	<0,01-0,04
Surface water down	0,06-0,22	0,30-1,04	0,01-0,13
Maas	0,04 (max)	< 0,5 (0,83 max)	0,12
Drinking water	< 0,01	0,3 (max)	< 0,01 (?)

Diclofenac: PNEC =0,05 µg/l
Metformine: PNEC = 780 µg/l
Clarithromycine: PNEC = 0,04 µg/l

Not relevant for human toxicty !?
European River Memorandum: < 0,1 µg/l
Indicator parameter drinking water directive: 1 µg/l

The Dutch Approach (Chain approach pharmaceuticals in water)

Ministerie van Infrastructuur en Waterstaat



Source approach **End-of-pipe**

Goal of the implementation program

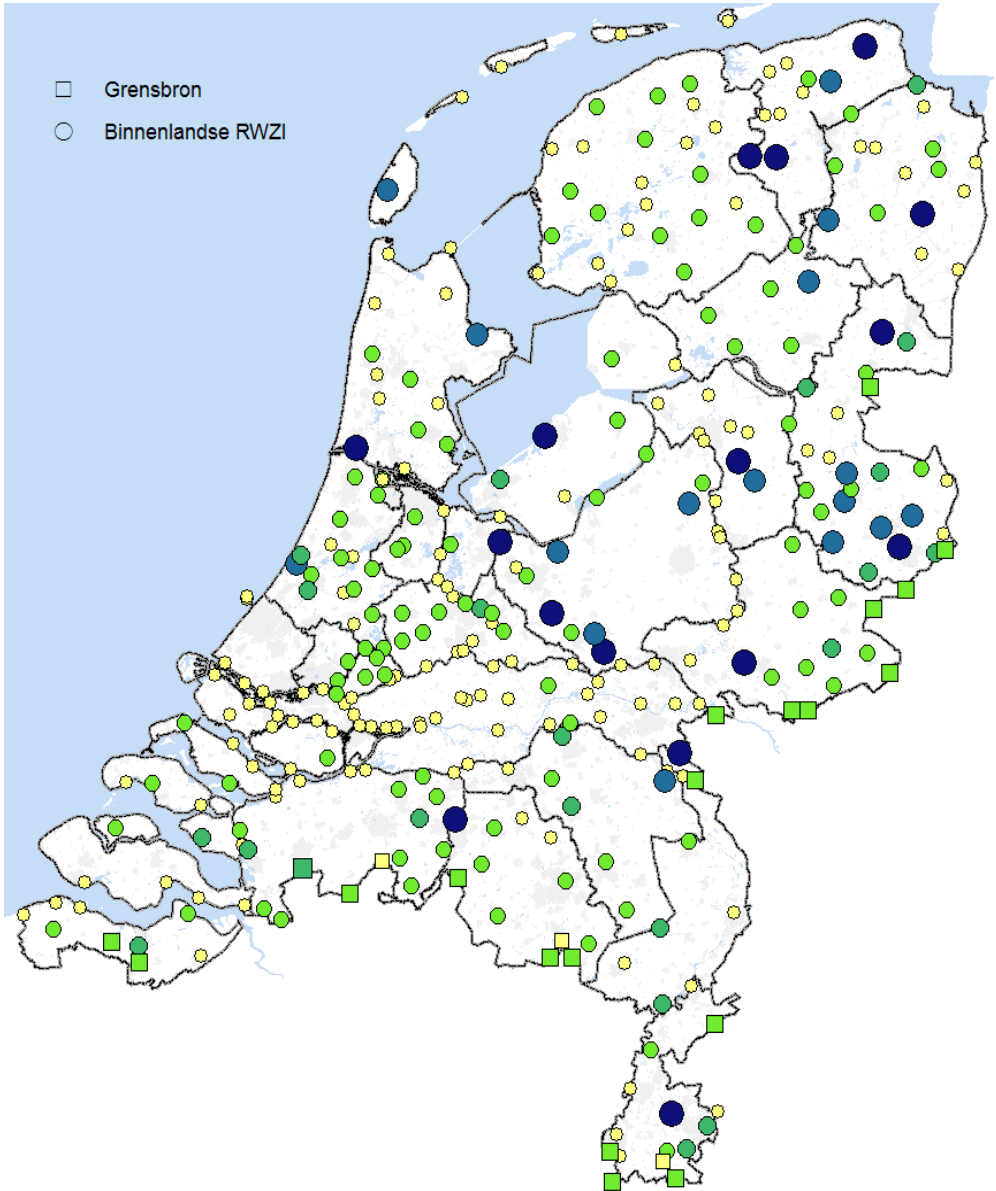
- Source approach will not be sufficient to prevent emissions
- Part of the problem is to be solved by additional treatment
- Proven technologies (active carbon and ozone)
- Financial contribution (60 M€ program) >2020
  Ministry of Infrastructure and Water Management
- Two tranches (2020-2024, 2024-2028)
- 70% removal of a selection of pharmaceuticals
  (7 best out of a list of 11)
- Start with a selected number of WWTP's
- Not wait, just start: Learning by doing!

Stowa national hotspot analysis WWTP's (model calculation)
Criterion: Concentration increase receiving surface water

Conclusion: about 150 of 314 WWTP's
no significant effect

Assumption: below 1 µg/l no effect aquatic ecosystem

About 100 hotspots



Second criterion:
Drinking water source

- <1 µg/l (2,2% van totaal)
- 1 - 10,7 µg/l (17,8% van totaal)
- 10,7 - 17,9 µg/l (20% van totaal)
- 17,9-23,7 µg/l (20% van totaal)
- >23,7 µg/l (20% van totaal)

List of 19 pharmaceuticals in one chemical analysis

Stof	Doel stof (na de evaluatie)
Som 4-,5-methylbenzotriazol	gidsstof
Azithromycine	monitoring
Benzotriazol	gidsstof
Candesartan	monitoring
Carbamazepine	gidsstof
Clarithromycine	monitoring
Diclofenac	gidsstof
Gabapentine	gidsstof
Hydrochloorthiazide	gidsstof
Irbesartan	gidsstof
Metoprolol	gidsstof
Propranolol	monitoring
Sotalol	gidsstof
Sulfamethoxazol	monitoring
Trimethoprim	gidsstof
Venlafaxine	gidsstof

Overview (proven) technologies (Stowa report 2017-36)

technology	removal	costs	Energy, GER	By-products
Powdered Activated Carbon (PACAS)	++	++	+/-	++
Active carbon filtration	++	+/-	+/-	++
Ozone + filtration	+++	+	+	- (bromate)
UV/H2O2	+++	+	-	+/-
Membrane filtration	++(+)	+/-	-	- (concentrate)
Natural treatments	+	++	++	++

Remark: combination of PACAS and ozone might be attractive to remove a broad range of contaminants

Versnellingsprogramma 1e tranche (12 waterschappen,14 rwzi's <2024)
Sommige plannen aangepast (o.a. rwzi's Dinther en Hapert)

OZONE

Wervershoof
(Hollands Noorderkwartier)

Horstermeer
(Amstel Gooi en Vecht)

Houten
Woerden
(De Stichtse Rijnlanden)

De Groote Lucht
(Delfland)

Winterswijk
(Rijn en IJssel)

Dinther
(Aa en Maas)

Soerendonk
(De Dommel)

PACAS

Leiden Noord
(Rijnland)

Groesbeek
(Rivierenland)

Oijen
(Aa en Maas)

Hapert
(De Dommel)

Simpelveld
(Waterschap Limburg)

Gedeeltelijk gefinancierd door
Ministerie van Infrastructuur en Waterstaat

Status quo (2024) first tranche

- PACAS (powdered active carbon)
  - WWTP Leiden Noord (HH Rijnland) (in operation)
  - WWTP Simpelveld (Ws Limburg)
  - WTTP Oijen (W Aa en Maas) (in operation)
  - WWTP Groesbeek (Ws Rivierenland)
- Ozone
  - WWTP Wervershoof (HH Hollands Noorderkwartier) (in operation)
  - WWTP Houten (HH De Stichtse Rijnlanden) (in operation)
  - WWTP Hapert (Ws De Dommel)
- Ozone + Active carbon filtration
  - WWTP Horstermeer (Waternet) (in operation)
  - WWTP Winterswijk (Ws Rijn en IJssel)
  - WWTP Dinther (Ws Aa en Maas)

First full scale PACAS installation in operation in 2021 (Water board Rijnland)

Small footprint..

Opening, September 30th 2021

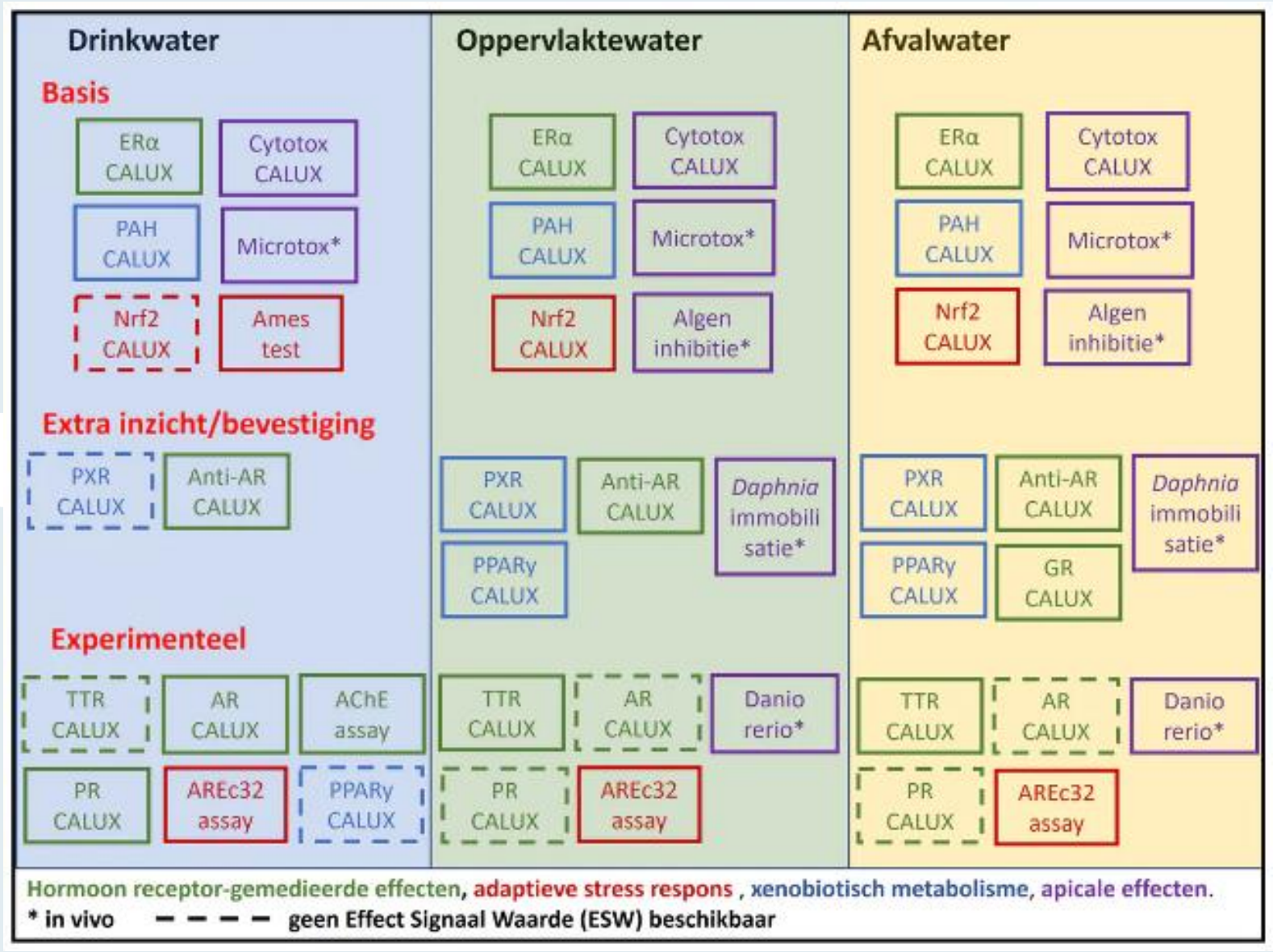
PACAS
(rwzi Oijen 2023)

Oxidatie met ozon
(rwzi Houten 2023)

Monitoring and sharing experiences

- Extended monitoring program to assess effectiveness of additional treatment steps
  - Chemical analyses
  - Bio-assays (ecotoxicological effects)
  - Side effects: nutrients, disinfection, AMR
- Community of Practice and User Groups

Effect monitoring using bio-assays



New insights during the program

- Introduction of a bromate standard for surface water (1 µg/l)
- Debate on trade off between water quality and energy consumption, CO_2 footprint and costs
- Experience with (for water boards) new technologies challenges getting installations in operation
- Limited availability of companies for designing and building
- Rising prices (lack fo materials)
- Debate on sampling and analysis
- Change of list of 11 compounds (presence in waste water)
- ..

Issues with proven technologies

- Bromate formation (strict standard of 1 µg/l in surface water)
- CO_2 foot print, energy consumption
- Costs
- Removal of a broad spectrum of organic micropollutants
- Standards for indvidual components (eg diclofenac Priority Compounds Directive)

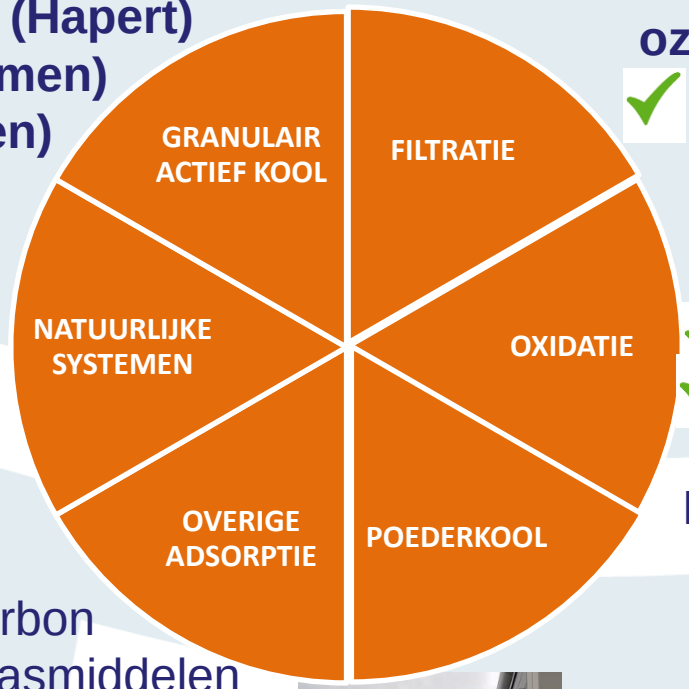
	Eenheid	PACAS	Ozon+zandfilter	GAK***
CO_2 footprint	g CO_2/m^3 *	116	119	325
Kosten	€/m^3 *	0,05	0,17	0,26
Verwijderingsrendement gidsstoffen Min I&W	% **	70-75%	80-85%	80-85%

- What is the most suitable technology? There is a need for innovative technologies

INNOVATION PROGRAM

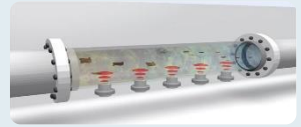
✓ ARVIA
O3-STEP (Horstermeer)
Continu Upflow µGAC + lucht (Hapert)
Continu Bio-GAC + lucht (Emmen)
BODAC - O2 (Emmen)

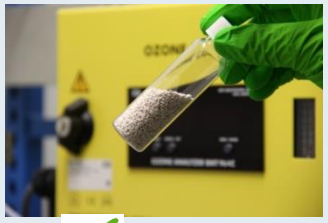
✓ **voorbehandeling – nano filtratie (Waterfabriek Wilp)**
nano filtratie effluent (Asten)
ozon met keramische micro filtratie (Wervershoof)
✓ Pharem - enzymen



✓ Verkenning natuurlijke systemen

Ultrasound en ozon (Winterswijk)
PACO3 (Leiden-Noord)
✓ **UV (Aarle Rixtel)**
✓ **Ozon (Aarle Rixtel)**
Microforce (O3 biofilm reactor; Walcheren)
B-O3 (biologische voorbehandeling en Horstermeer of Amstelveen)





✓ Fossil free carbon
✓ Zeolieten in wasmiddelen
✓ Fossil free adsorbentia in zandfiltratie
AdOx, zeoliet met filtratie (Leiden)
Dexsorb, cyclodextrines (Lelystad)

✓ PACAS + Fe
PACAS Nereda (Simpelveld)
✓ **PAC+doek filtratie (Vinkel)**

Promising technologies

- Combinations of active carbon and ozone
- O_3-Step (removal of bromate in anaerobic carbon filter)
- BODAC (Aerated Biologically active carbon filtration)
- Adox (zeolites) and Dexsorb (developed for PFAS)
- Hollow fiber nanofiltration (expensive) -> reuse

Pilot plants..

Dilemmas and Challenges for further implementation

- Framework water quality directive
  (pharmaceuticals not included yet, investments for nutrients <2027)

- Increasing number of (organic) contaminants will appear in WTTP effluent, upcoming standards for individual compounds (eg diclofenac)
- Increased insight in presence and (eco)effects of contaminants in water
- Need for removal of a broad spectrum of organic micropollutants?

- Meet multiple goals: water quality, climate foot print, circular economy,..
- Opportunity: reuse of WWTP effluent, business case!?
- Fit for purpose treatment (and flexible towards future developments)

Upcoming Urban Waste Water Directive: the next step

- 80% removal (compared to 70%) of a selected (slightly different) group of pharmaceuticals, higher standard?
- Treatment plants > 150.000 pe
- Hotspots (location with increased risk), Dutch hotspot analysis?
- Standards for priority compounds (eg diclofenac)

- Proven technologies sufficient?
- 2nd tranche: Implementation of technologies from the innovation program: future proof technologies!?
- Fit for purpose treatment: not one technology fits all..

Challenges for the water boards

- Focus on pharmaceuticals or other components as well?
- Which WWTPs?
- Which technology?
- Investments?
- Energy consumption and CO_2 foot print?
- Availability of sufficient personnel and manufacturers
- Planning investments for the next plan periods (2028-2033, 2034-2039, 2040-2045)

A major effort!

Thank you for your attention!

Maarten Nederlof, m.nederlof@wrij.nl

stowa

Rijkswaterstaat
Ministry of Infrastructure and Water Management