Waterschap
Aa en Maas

Pilot Direct Nanofiltration and UV/H_2O_2

Stowa Congress: Tackling Micropollutants in Wastewater
Results of the Dutch Innovation and Implementation Programme

Aquatech Amsterdam

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veilig voldoende schoon water

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1. Reason for the pilot

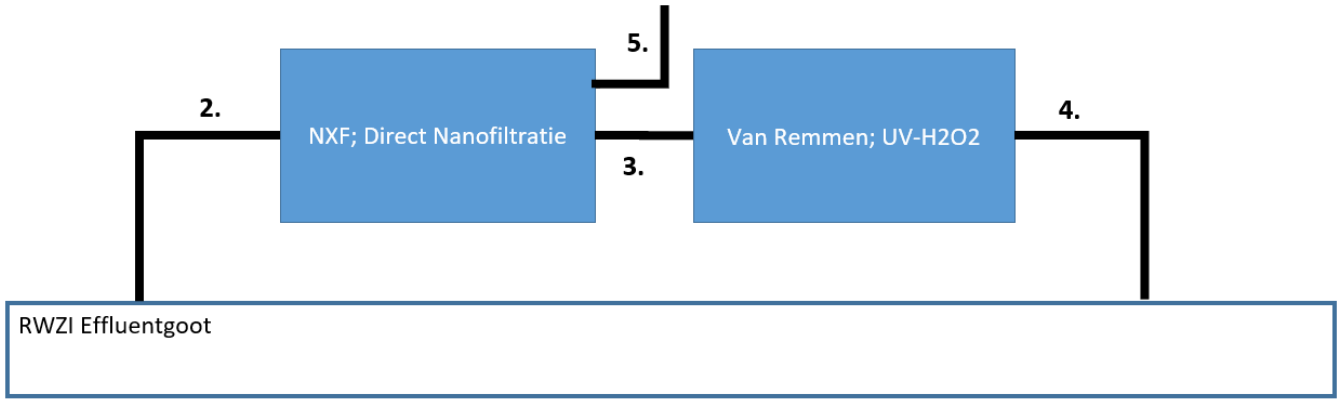
- In the summer of 2021, a feasibility study was carried out with direct nanofiltration and UV/H_2O_2 at wwtp Asten. This is called the Water Factory.
- Opportunities from the Water Factory to make the post-purified effluent from wwtp Asten suitable for high-quality reuse, such as irrigation water for greenhouse horticulture and process water for industry.
- Follow-up research falls under the IPMV program.
- Pilot installation ran from November 2021 to February 2023.

2. Research objectives

- Determination of the **removal efficiencies** of the IPMV **guide substances** over the pilot installation.
- Determining the **biological effects** (reduction of ecotoxicology).
- Determining the **CO_2-footprint** (in accordance with the IPMV CO_2 model).
- Translating the pilot installation into **operational costs** for a **full-scale installation** of 100.000 p.e. (energy, chemical consumption, maintenance, etc.).
  - **€/m3 treated water?**
- In addition to the IPMV program, we investigate antibiotic resistance where possible in the removal of nutrients, heavy metals, pathogens, bacteria and PFAS.
- Insight into the reuse applications in relation to the different membrane types and UV/H2O2 dosages.
- Translation of the effects of concentrate flow on the existing biological treatment, followed by an assessment of the usefulness and necessity of concentrate treatment.

3. Project partners

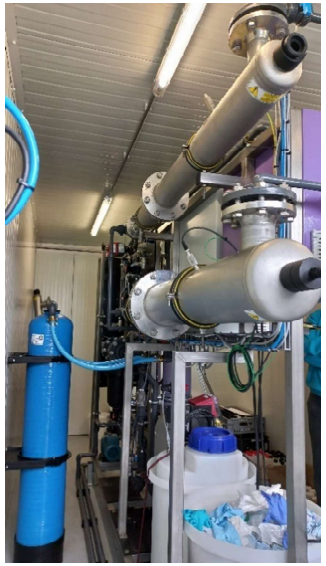
4. Configuration and settings



Membrane	UV-dosage (J/m²)	H_2O_2-dosage (mg/l)
DNF40 (400 dalton)	8.000	10
DNF80 (800 dalton)	3.000, 6.000, 12.000	10, 15
DNF120 (1.200 dalton)	4.000, 12.000	15, 20

5. WWTP Asten

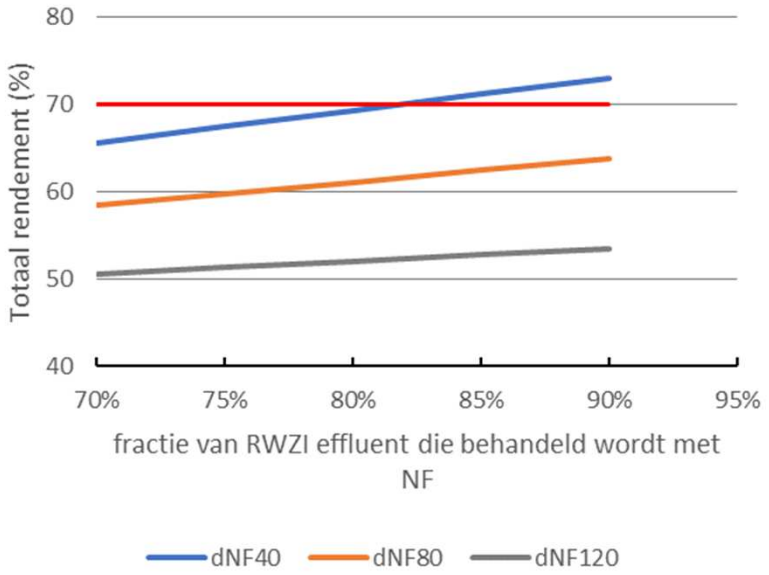
6. Pilot layout



7. Results nanofiltration – removal of guide substances

Removal efficiencies of NF alone with three membrane types, compared to wwtp effluent.

Guide substance:	dNF40	dNF80	dNF120
som 4- en 5-methyl-1H-benzotriazol	-41%	-2%	-44%
1,2,3-benzotriazool	11%	-52%	0%
carbamazepine	35%	6%	-4%
diclofenac	89%	62%	27%
gabapentine	74%	41%	25%
hydrochloorthiazide	21%	7%	17%
Irbesartan	95%	96%	61%
Metoprolol	35%	10%	19%
Sotalol	18%	3%	6%
Trimethoprim	-120%	40%	0%
Venlafaxine	81%	50%	20%
Best 7 out of 11 guide substances	**61%**	**44%**	**25%**
Average of 11 guide substances	**27%**	**24%**	**12%**



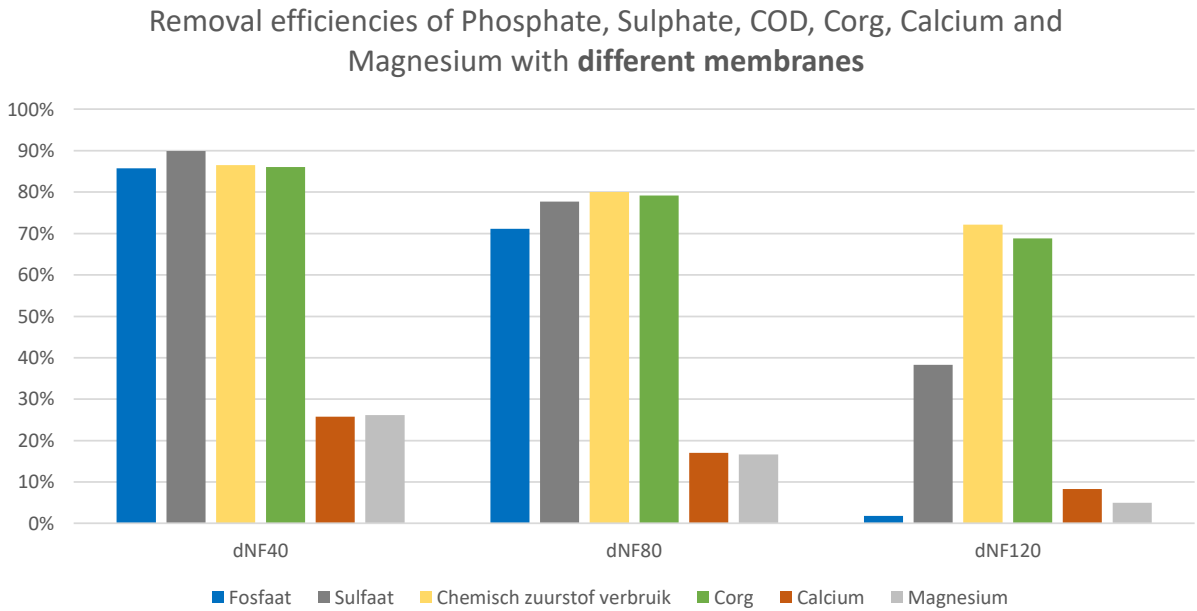
Total removal efficiency of the 7 best out of 11 guide substances at a wwtp that treats a fraction of the effluent with NF.
Assuming a removal efficiency of 40% of the guide substances in the biological treatment of the wwtp.

8. Results UV/H_2O_2 – removal of guide substances

Removal efficiency of UV/H_2O_2 at different doses, compared to spiked NF permeate.

Guide substance↓ Membrane: UV-dose (J/m²): H_2O_2-dose (mg/l):	dNF40 8.000 10	dNF80 3.000 10	dNF80 6.000 15	dNF80 12.000 15	dNF120 4.000 15	dNF120 12.000 20
som 4- en 5-methyl-1H-benzotriazol	22%	59%	97%	97%	64%	97%
1,2,3-benzotriazool	48%	66%	98%	99%	61%	98%
Carbamazepine	56%	66%	98%	98%	67%	97%
Diclofenac	93%	95%	92%	94%	90%	92%
Gabapentine	58%	44%	91%	92%	45%	93%
Hydrochloorthiazide	49%	63%	94%	95%	51%	91%
Irbesartan	97%	97%	0,0%	0%	56%	83%
Metoprolol	64%	70%	97%	99%	65%	98%
Sotalol	73%	76%	97%	98%	58%	97%
Trimethoprim	-40%	43%	93%	90%	60%	90%
Venlafaxine	88%	88%	80%	75%	63%	71%
Best 7 out of 11 guide substances	**76%**	**80%**	**96%**	**97%**	**67%**	**96%**
Average of 11 guide substances	**55%**	**70%**	**85%**	**85%**	**62%**	**92%**

9. Results – removal of macro parameters and PFAS



- Total concentration of PFAS in the influent of the pilot ranged from 12 – 34 ng/l.
- PFAS concentration after NF decreases in all cases. With the finest membrane (400 Dalton) the reduction is approximately 90%. The reduction with the 1200 Dalton membrane is approximately 35%.
- The level of UV dose does not appear to play a decisive role in the removal of PFAS within the tested range (4000 – 12000 J/m^2).

10. Results – removal of (antibiotic resistant) bacteria

Measuring days	Used membrane
24-5-2022	dNF40
21-6-2022	dNF40
6-9-2022	dNF120
13-9-2022	dNF120
4-10-2022	dNF120
11-10-2022	dNF120
15-11-2022	dNF80

E.coli (kve / L)	influent NF	effluent NF	effluent NF / UV
24-5-2022	8,5E+05	1,0E+02	1,0E+02
21-6-2022	1,2E+05	<10	<10
6-9-2022	5,0E+05	1,0E+02	<10
13-9-2022	7,5E+05	3,0E+02	<10
4-10-2022	9,5E+04	1,0E+02	<10
11-10-2022	1,1E+05	<10	<10
15-11-2022	3,6E+05	<10	<10

ESBL (kve / L)	influent NF	effluent NF	effluent NF / UV
24-5-2022	6,3E+03	<10	<10
21-6-2022	2,1E+03	<10	<10
6-9-2022	3,7E+03	<10	<10
13-9-2022	4,5E+03	<10	<10
4-10-2022	6,5E+02	<10	<10
11-10-2022	4,4E+02	<10	<10
15-11-2022	1,7E+03	<10	<10

11. Summary performances

	UNIT	PACAS	Ozone + Sand Filtration	NF+AOP (UV/H_2O_2)
CO_2-footprint [1]	g CO_2/m^3	122	128	244
Costs [1]	€/m^3	0,05	0,17	0,47
Removal Efficiency Dutch guide substances[2]	%	70-75%	80-85%	88%

[1] 1 Per treated m3 wastewater: peak dry weather flow must be treated. ***Please note: standardized cost and CO2 levels for 2018****; recalibration of all CO2- and cost levels will take place during the evaluation of the Innovation Program in 2024*

[2] Overall Removal Efficiency of effluent wwtp to influent wwtp (including bypass post treatment) for 7 of 11 guide substances: benzotriazool, carbamazepine, diclofenac, irbesartan, gabapentine, metropolol, hydrochloorthiazide, mixture of 4- en 5-methylbenzotriazool, sotalol, trimethoprim en venlaflaxine in every 24h or 48h flow or time proportional sample. The sampling has to take the hydraulic retention time of the wwtp into account.

Consequences stricter removal efficiencies Proposal EU Urban Wastewater Treatment Directive (**80% in EU** in stead of 70% in NL and different guide substances):

- PACAS will have a footprint of 160 g CO2/m3 and a cost level of € 0,08/m^3; **no changes for ozone and NF+AOP.**

12. Conclusions

- When using **dNF 40 membranes**, an average efficiency of **70%** can theoretically be achieved on **7 of the 11 guide substances** if:
  - **82%** of the wwtp effluent **is treated** and
  - all guide substances returned with the **concentrate** are additionally **removed in the wwtp**.
- The membranes dNF 80 and dNF 120 are not able to retain the guide substances to a sufficient extent to comply with the IPMV guidelines (70% removal of 7 out of 11 guide substances).

- In combination with advanced oxidation (UV/H_2O_2), removal efficiencies increase significantly:
  - With the **dNF 80 membrane, a UV dose of 6000 J/m² and a H_2O_2 dose of 15 mg/l**, a total efficiency of **88%** on **7 of the 11 guide substances** can be achieved if **82%** of the wwtp effluent **is treated**.

- The water produced is completely **free of pathogens**, has **no colour** and has an **organic carbon content** of **less than 2 mg/l**.

- The **costs** of post-treatment with **nanofiltration and UV/H_2O_2** for a wwtp of 100,000 p.e. are **€0,47/m3 treated water** (excluding costs for processing the concentrate). The **CO_2-footprint** is **244 g CO_2/m³ treated water.**

Thank you for your attention!

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stowa

Ministry of Infrastructure and Water Management

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