Demonstrating synergy between H_2 production and wastewater treatment at WWTP Hessenpoort

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Round 6 Resource recovery

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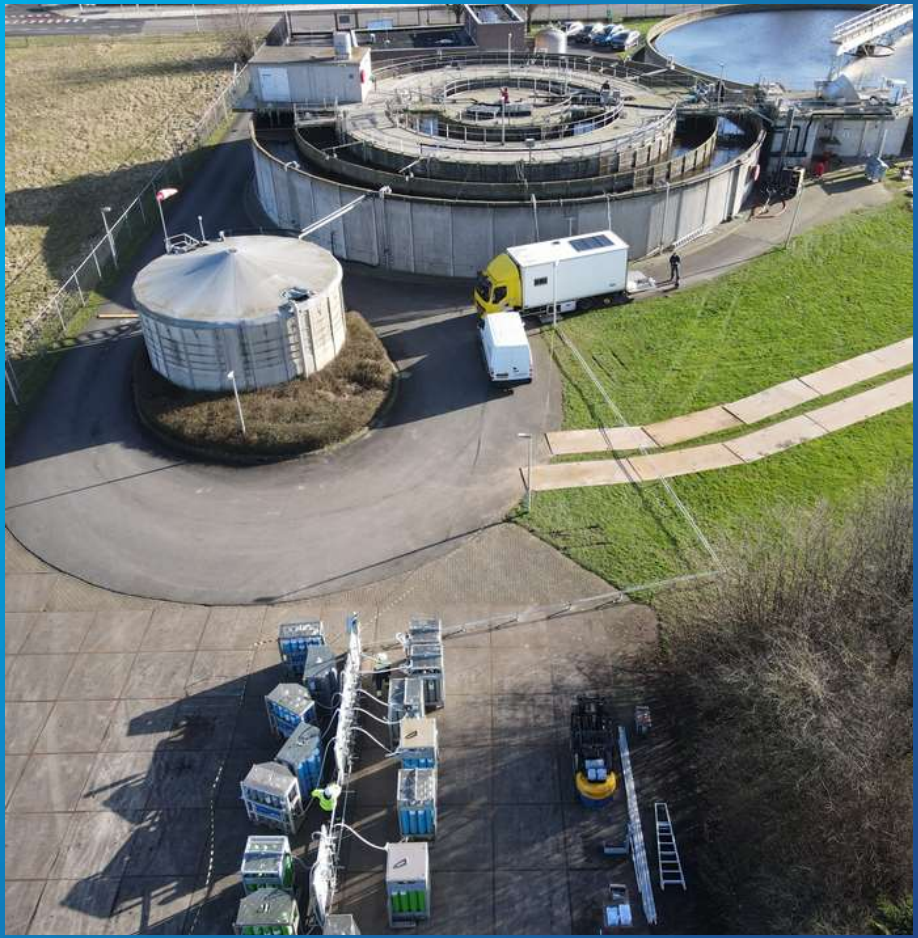
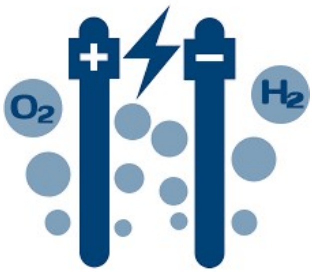


H_2 is one of the future energy solutions

Making H_2 with an electrolyser: 9 kg H_2O + electricity → 1 kg H_2 + **8 kg O_2** + heat



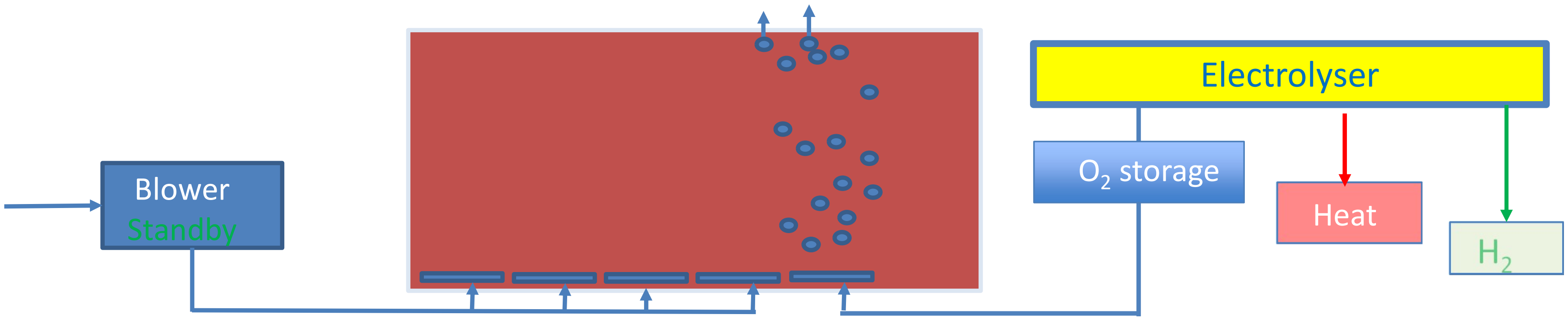
What to do with off-gas O_2?

$\%O_2 > 99.99\%$ **= Pure Oxygen (PO)**
Pressure 0-10 bar (depending on electrolyser)

Using Pure Oxygen (PO) from H_2

Aeration with air not very efficient: 21%O_2 + 79%N_2 + 1% other gasses

- Aeration consumes > 50% of all energy for wastewater treatment
- Use *“Off-gas O_2” (PO)* can reduce this energy consumption to zero
- Maintain normal aeration with blowers for redundancy/fall back



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Fases of research

Fase 1 testing PO in a small scale reactor with a fine bubble diffuser (2021) ✓

Fase 2 testing PO in a section of the WWTP Hessenpoort (2022) ✓

Fase 3 DEMO Fase (2024-2028):

- *electrolyser on site*
- *continues PO dosage*
- *close monitoring of pH and N20*

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Topics of research

When using PO instead of air, is there a difference in?

1) Oxygen transfer from gas to water
2) N_2O emissions from the activated-sludge tank
3) pH in the activated-sludge tank
4) Other sides effects;
   - mixing in the activated-sludge tank
   - deterioration of diffusers
5) Safety issues

Oxygen transfer tests

Method

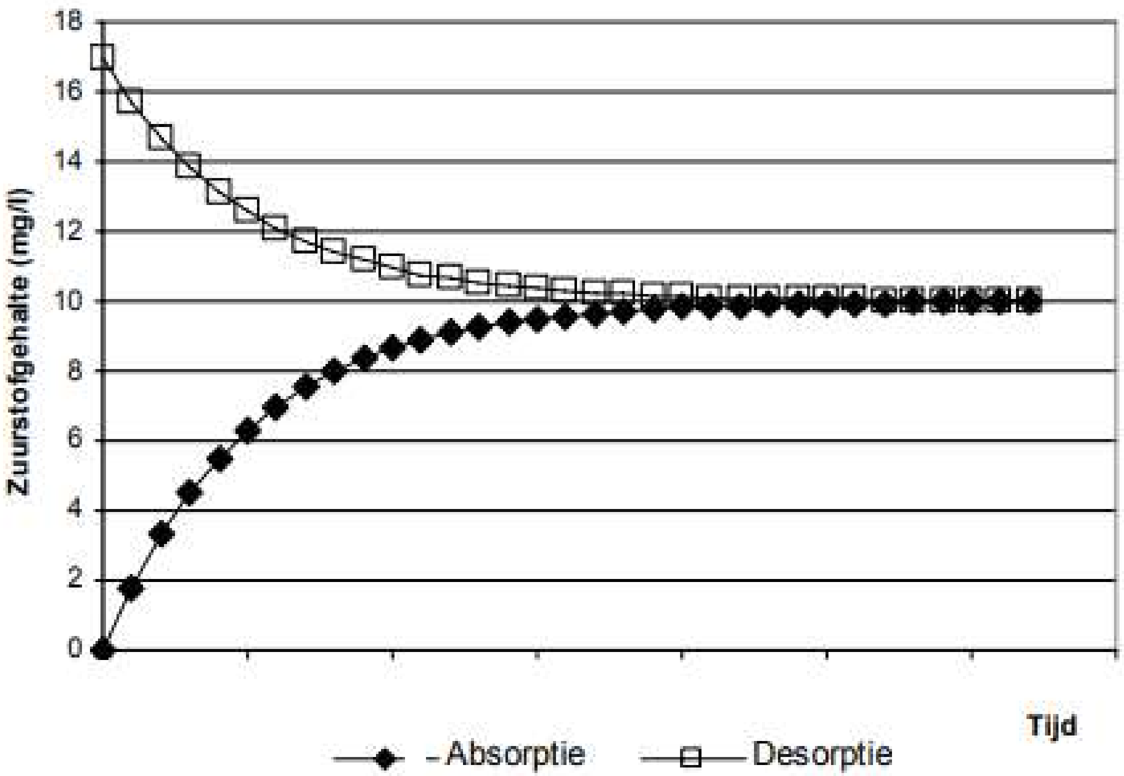
Adsorption en desorption test
German standard DWA-M 209

Adsorption to test PO
Desorption to test air

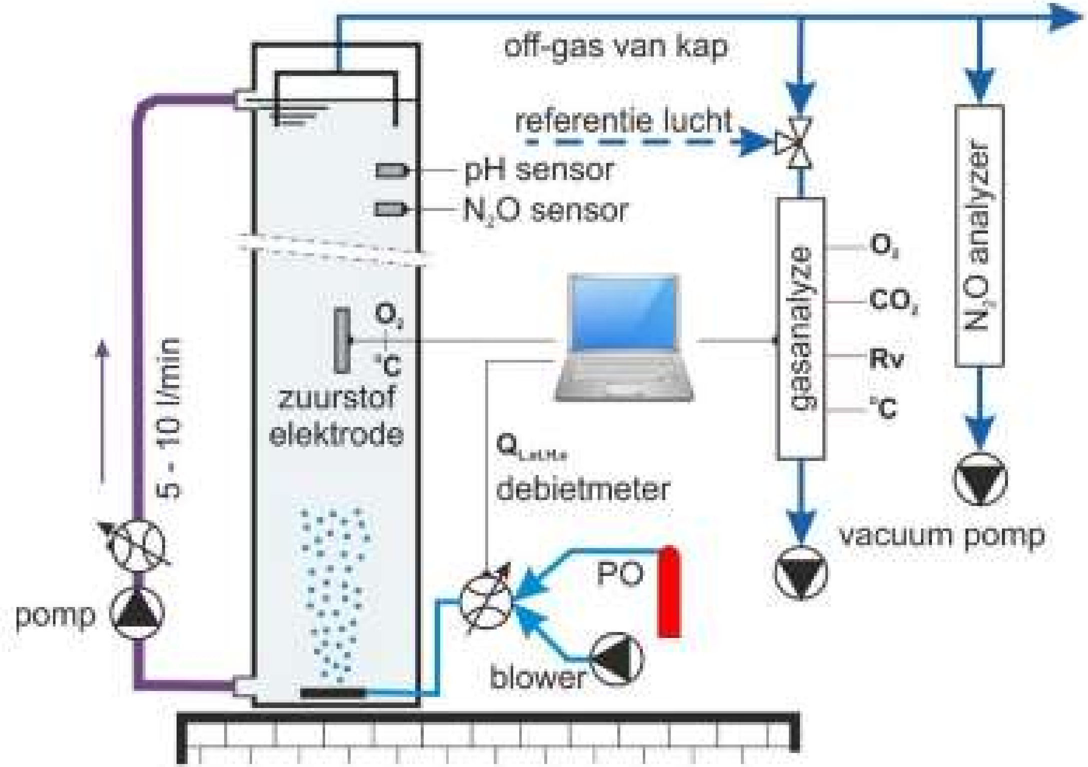
Measurement
Alpha – resistance transport gas-water in dirty water
Standard Specific Oxygen Transfer Rate (SSOTR)
Standard Specific Oxygen Transfer Efficiency (SSOTE)

Small scale reactor (fase 1)
10 tests in drinking water
4 test in activated sludge water

Section of a WWTP (fase 2)
4 test in activated sludge water



Fase 1 testing PO in a small scale reactor



Diffuser: EPDM dome 175 mm

meetopstelling

Fase 1 testing PO in a small scale reactor

Results (selection of 4 tests, in total 14 tests where done)

Smal scale reactor	Gasload per difusser Nm^3 per element per hour	alpha	Specific Oxygen Transfer Rate (SSOTR) ($gO_2/Nm^3.m$)	Specific Oxygen Transfer Efficiency (SSOTE) (%O_2 of total O_2)
PO drinking water	0.9	1.0	114	36
Air drinking water	0.9	1.0	25	38
PO activated sluge	1.0	0.69	113	36
Air activated sludge	1.0	0.44	25	37

Test	SSOTR_air/SSOTR_PO	Ratio
Drinking water	114/25	4.6
Activated sludge	113/25	4.6

Fase 1 testing PO in a small scale reactor

Results

Test	Number of test	Average ratio SSOTR_PO/SSOTR_air
Drinkwater PO and air	10	4.8
Activated sludge PO and air	4	4.6

Results fit with the theoretical expectations of Henry's law

Air 20.8% O_2

PO 99.99% O_2

PO/Air = 99.99 / 20.8 => 4.8

Henry 20°C for oxygen	4,09E+09	Pa
used pressure	1,00E+05	Pa
atmospheric pressure	1,01E+05	Pa
oxygen content air	20,95	%
partial pressure air at 1 bar	20950	Pa
at 1 atm	4389	Pa
molar mass water	0,018	kg/mol
molar mass oxygen	0,032	kg/mol
density water 20 °C	998	kg/m3
saturation conc. in air at 1 bar	9,088	g/m3
at 1 atm	9,206	g/m3
saturation concentration PO	43,38	g/m3
at 1 atm	43,94	g/m3
Ratio PO/air	4,77	

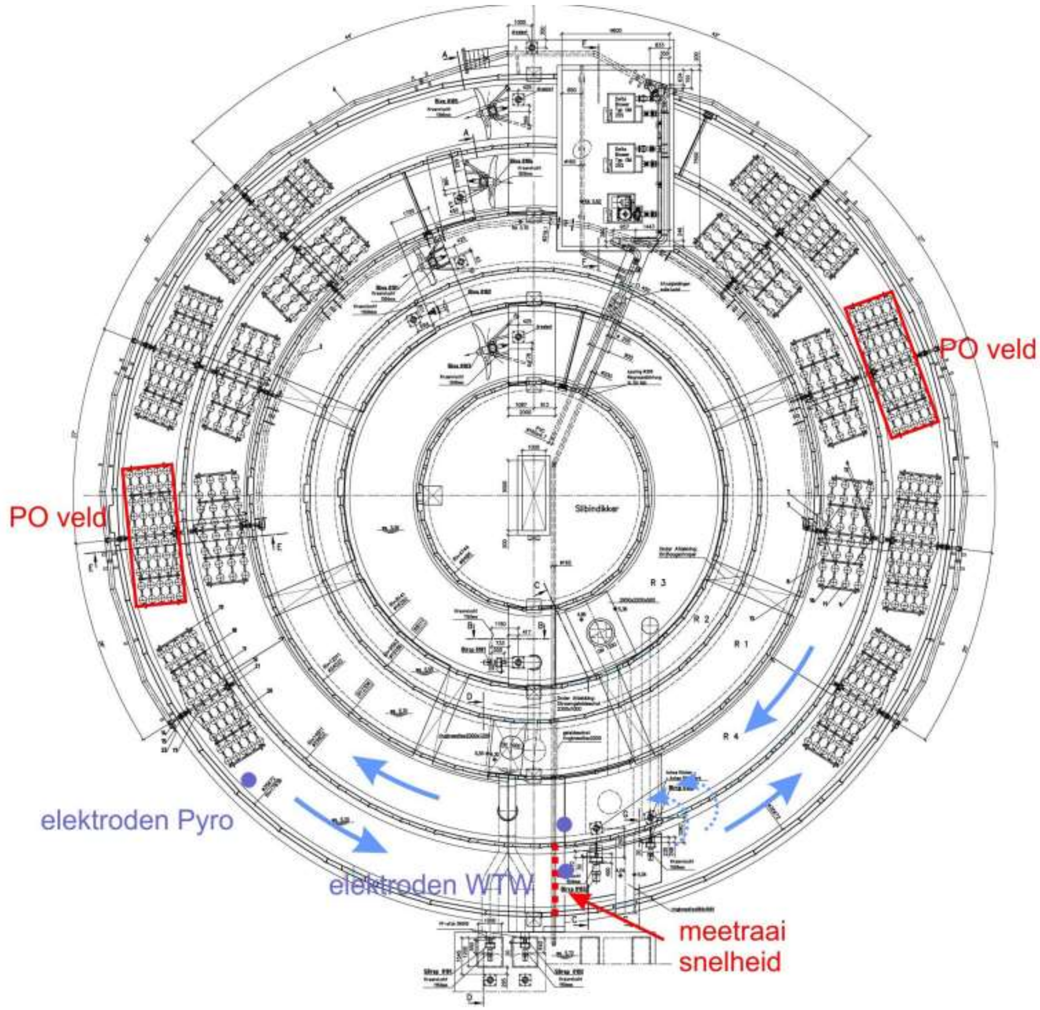
Fase 2 testing PO in a WWTP section

Testsite:

- Activated sludge process
- 25.000 PE Capacity, average load 15.000 PE
- Outer ring is completely aerated
- 8 liftable racks with diffusers
    - 2 connected to PO: temporary supply from storage facility
    - 6 connected to air

4 days of testing:

- 4 Oxygen transfer tests
- 2 performance test with influent feeding



Fase 2 testing PO in a WWTP section

Measuring :

- pH
- Dissolved Oxygen (DO)
- N_2O (gas and liquid)
- NH_4
- NO_3
- Suspended solids
- Alpha
- 24 hr sampling

Fase 2 testing PO in a WWTP section

Disconnect air supply

Last minute repairs at PO supply

Manual control panel PO dosage

Preparing the PO supply
2000 kgPO in a storage
Temporary PO connections and 2 control panels

Fase 2 testing PO in a WWTP section

Liftable rack with diffusers

Cleaning of the diffusers

Fase 2 testing PO in a WWTP section

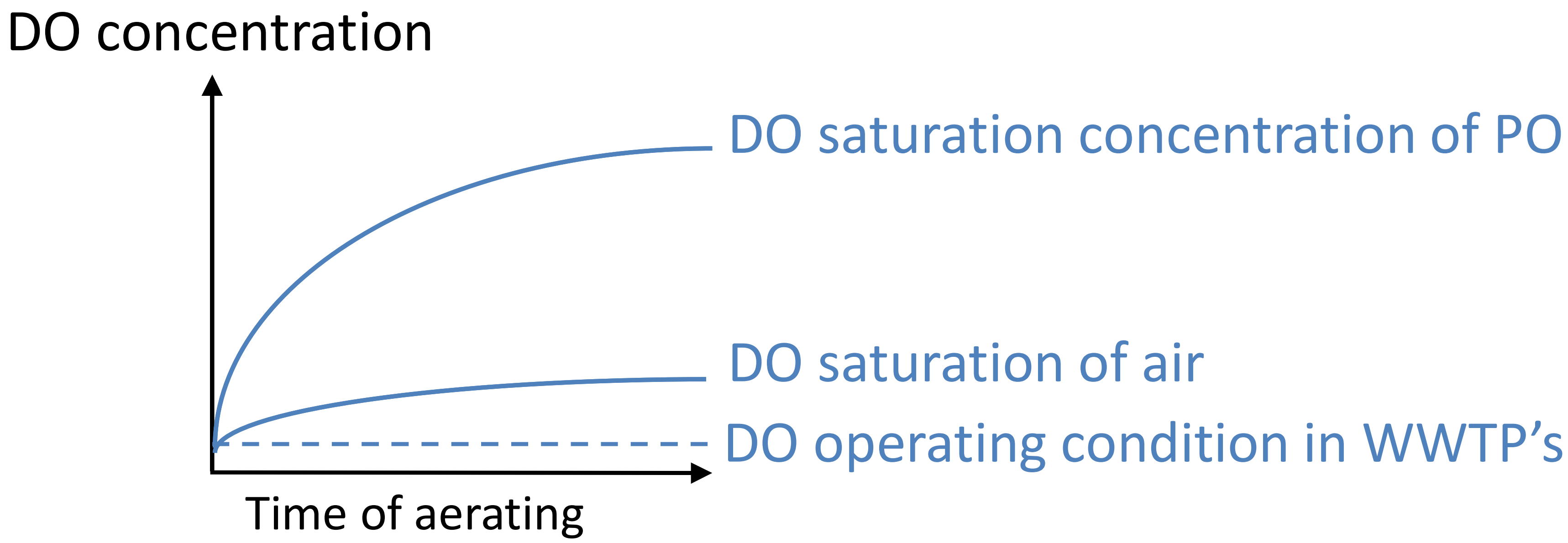
Results Oxygen transfer tests

Test	Gasload Nm^3/diffuser.hr	Alpha	Standard Specific Oxygen Transfer Rate (SSOTR) ($gO_2/Nm^3.m$)	Standard Specific Oxygen Transfer efficiency (SSOTE) (%O_2 of total O_2)
PO low gasload	1.0	0.69	96	30
Air low gasload	1.0	0.74	22	32
PO high gasload	3.3	0.74	56	17
Air high gasload	3.3	0.69	15	23

Test	SSOTR_air/SSOTR_PO	Ratio
Low gasload	96/22	4.4
High gasload	56/15	3.6

Lower ratios most likely a mixing issue

Difference in *driving force* PO and air



PO compared to air has a stronger driving force to dissolve

In total, with PO about 5.5x less gas is required

Other results Fase 1 and 2

pH

- pH drops 0.1 to 0.2 within several hours with PO aeration
- Trial was too short to fully investigate pH effect
- Decrease reversible by briefly aerating with air

N_2O

- Hardly any emissions were observed when running a stable process
- emissions were not higher and are most likely lower due to less stripping of N_2O

Mixing

- Use of PO decrease resistance for mixers
- Use of PO reduces turbulence

Safety

- PO lowers flammability → no sparking devices etc
- Extra O2 gas sensors

Diffusers

- PO could lead to acceleration of the aging process because of dry air

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Synergy of H_2 production and WWTPs

Normal aeration of outer ring with all aeration elements

PO dosage on 2 of the 8 diffuser stacks

- Technically "relatively easy" conversion from air to PO
- 4 to 6 times less gas volume required
- Significant energy savings possible
- pH controllable with briefly aeration
- N_2O emissions most likely significant lower due to less stripping

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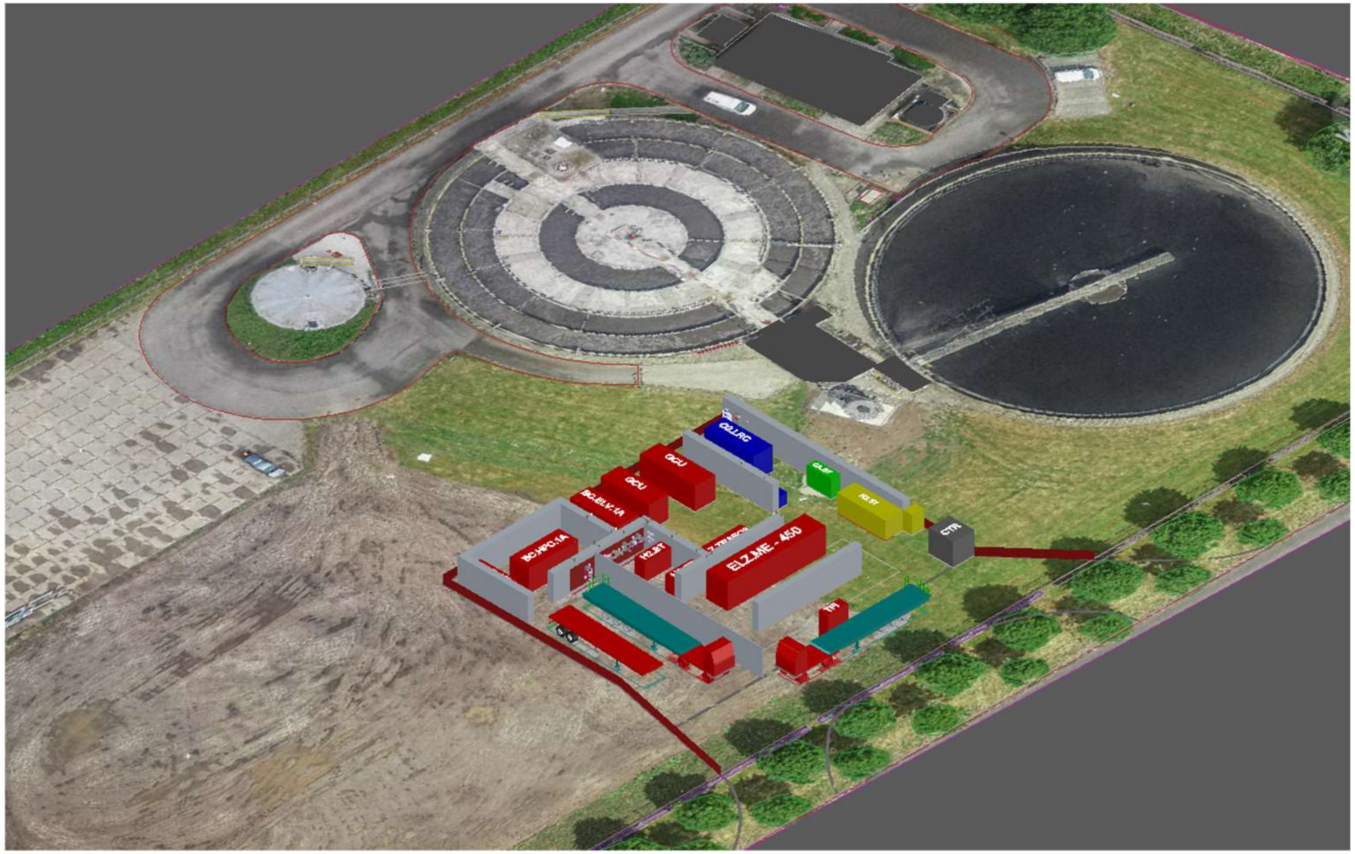
Fase 3 DEMO Fase (2024-2028)

Topics

- Increase O_2transfer
- Reduce N_2O
- Control pH
- Use heat
- Use effluent for H_2



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Thank you for your attention!

Further information:

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Or STOWA report 2022-51

(public download)