Groundwater Denitrification Using Hydrogen Gas in a New Reactor Type

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September 2016

Short background

- Nitrate pollution (>10 mg NO_3^--N/L according to EPA)
- Physicochemical methods (RO, IEX, Electrodialysis)
- Biological denitrification:
  - Nitrate reduction to N_2 gas by denitrifying bacteria under anoxic conditions.
  - Electron donor can be organic or inorganic and must be added to water.
  - Cell Yields are lower for autotrophic bacteria using inorganic electron donors (30% of heterotrophs).

Hydrogenotrophic denitrification

- Why hydrogen?
  - Clean: Low cell yield, no organics addition, no harmful by-products
  - Does not persist in water
  - Cheap
- So why **not**?
  - Mass transfer limitations -> low rates
  - Low hydrogen utilization-> financial asp
  - Hydrogen flammability/explosiveness -> **safety a**

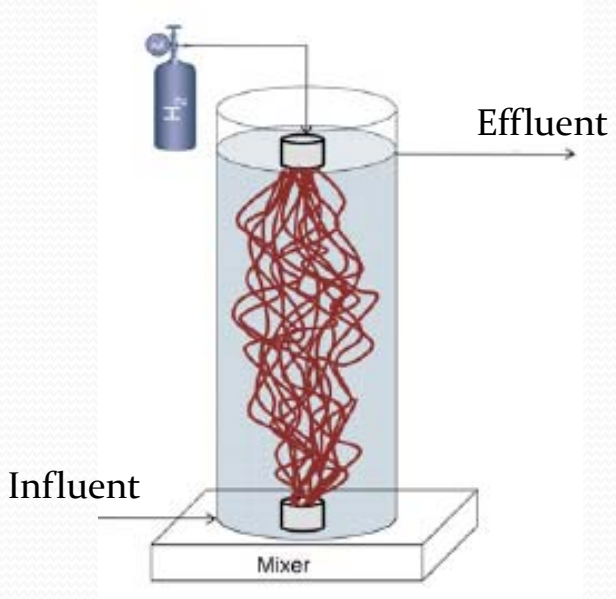
Commercially limited!!!

How can hydrogen transfer be increased economically and safely?

One possible solution:

Membrane biofilm reactor (MBFR)
Lee & Rittman, 2002

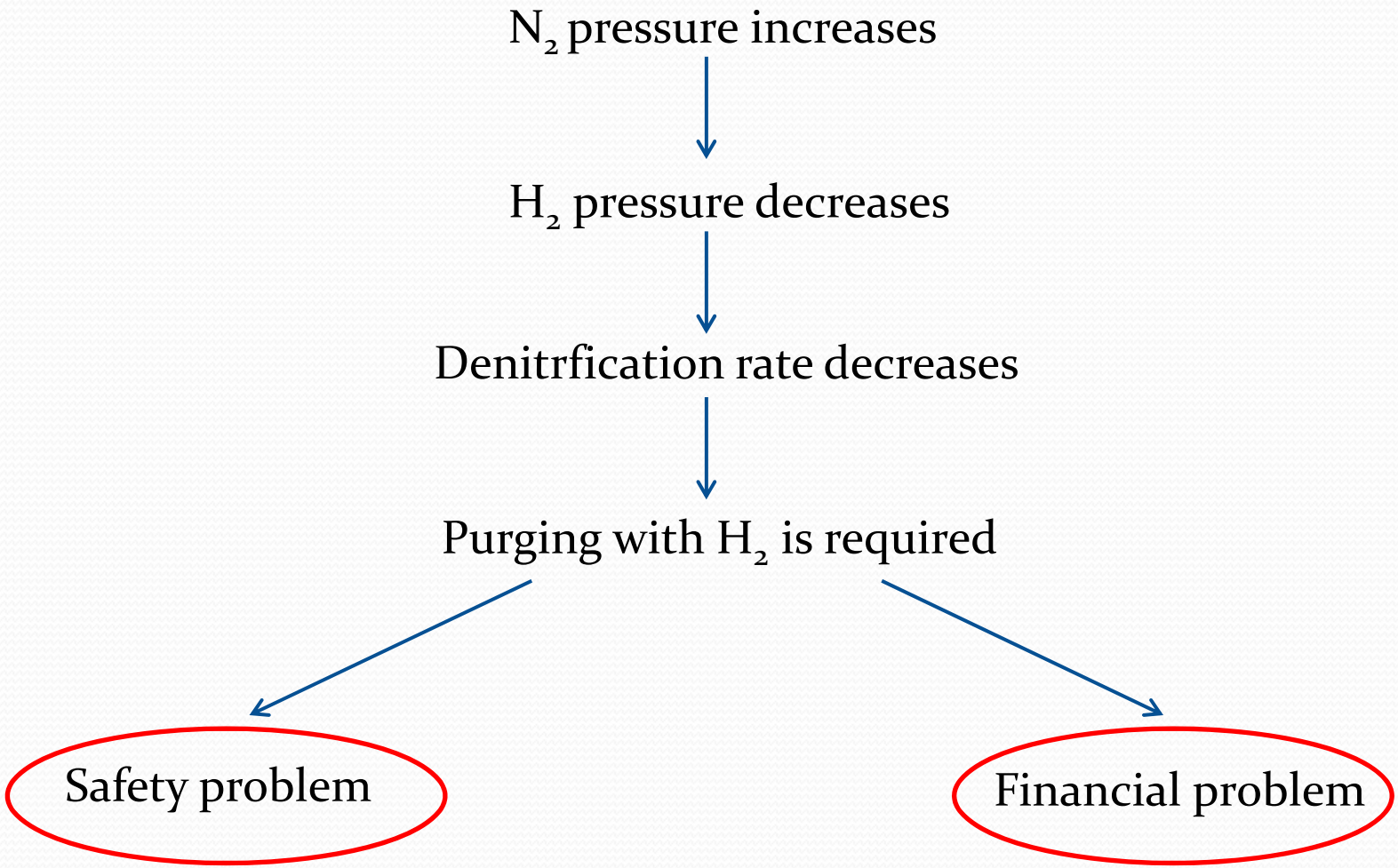
Denitrification rates < 1 g N /($L_{reactor}$ x day)



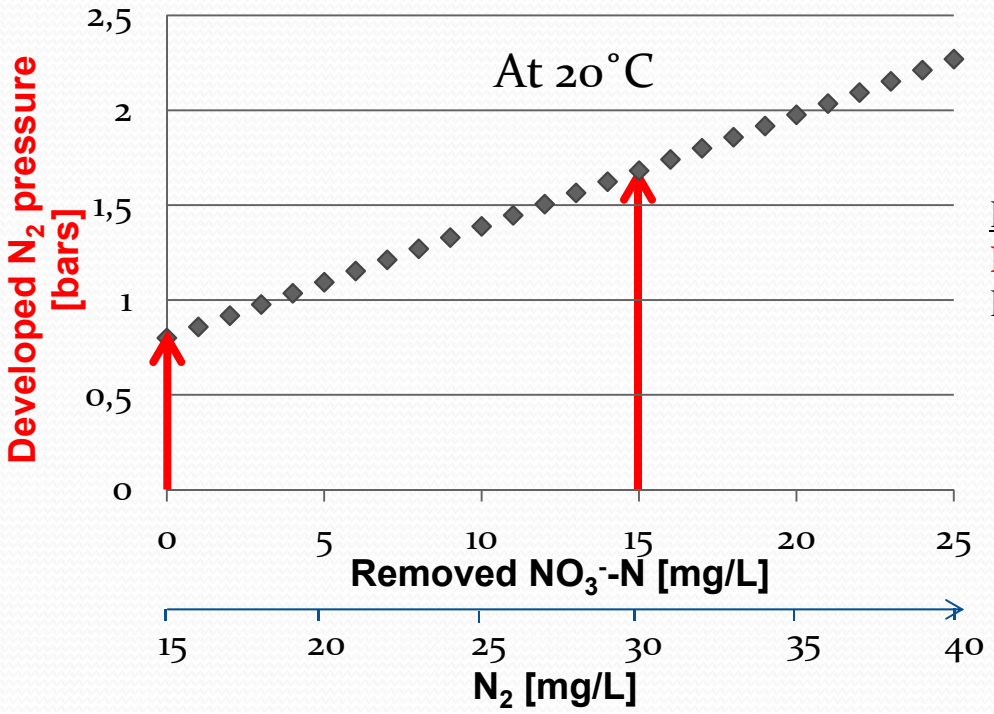
Our alternative solution:

A new reactor type with closed headspace!!!

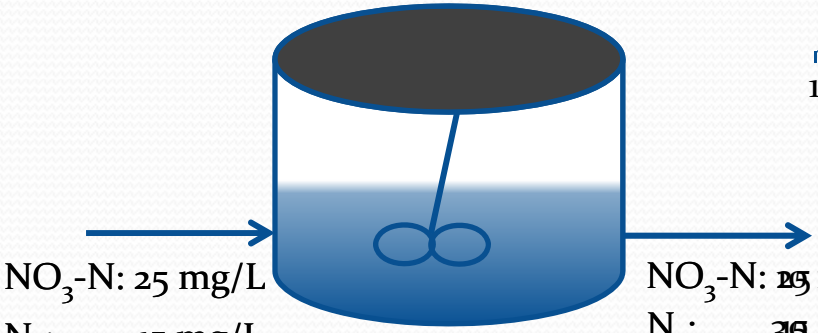
The common misconception of closed headspace denitrifying reactor



N_2 accumulation in closed headspace – does it really happen???



Henry's law:
P = H x C
H [bar * L / mg]



NO_3-N: 25 mg/L
N_2: 15 mg/L

NO_3-N: 15 mg/L
N_2: 35 mg/L

Our proposed system

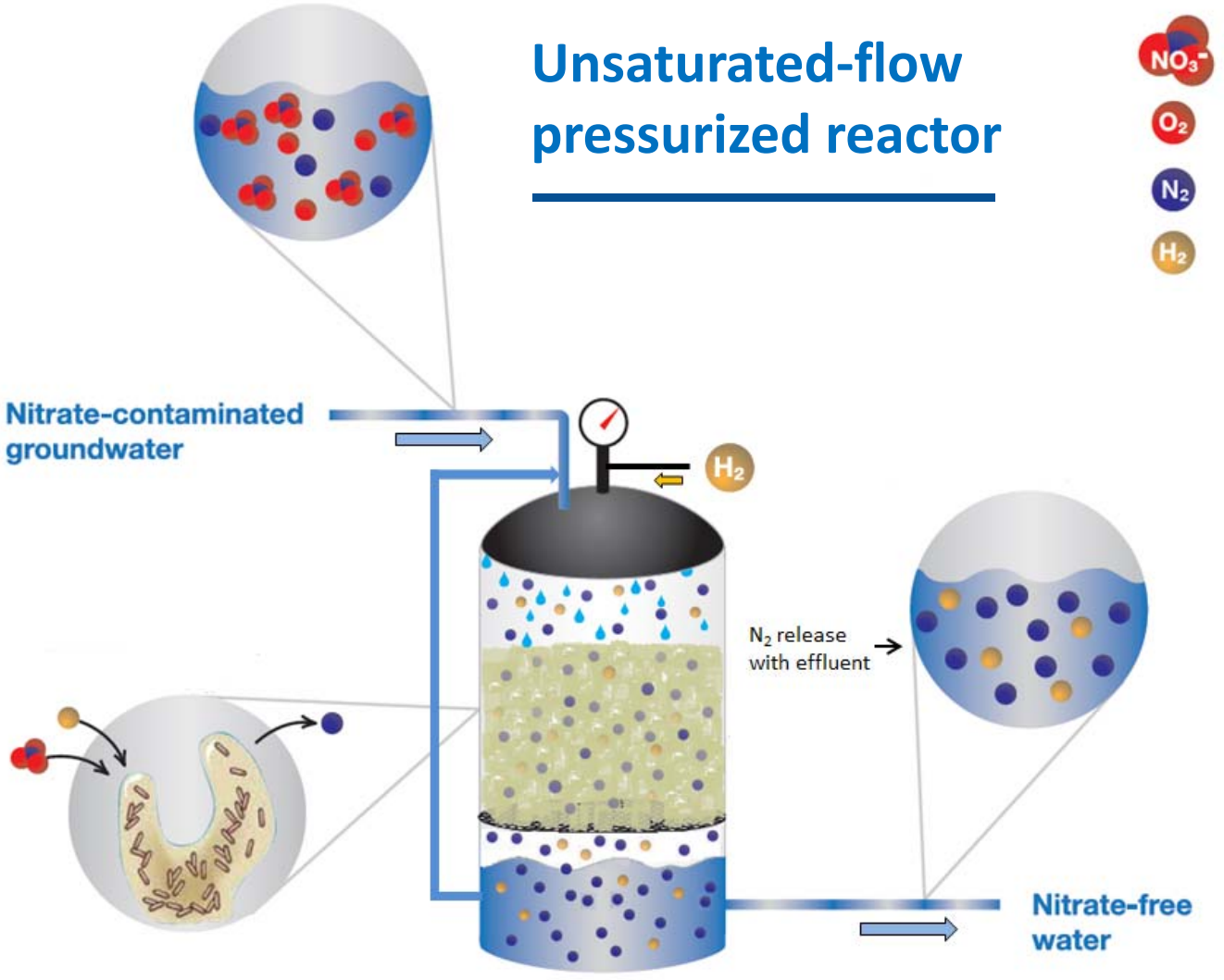
Main Characteristics:

- Closed Headspace (economic and safe)

- High surface area for bacterial growth

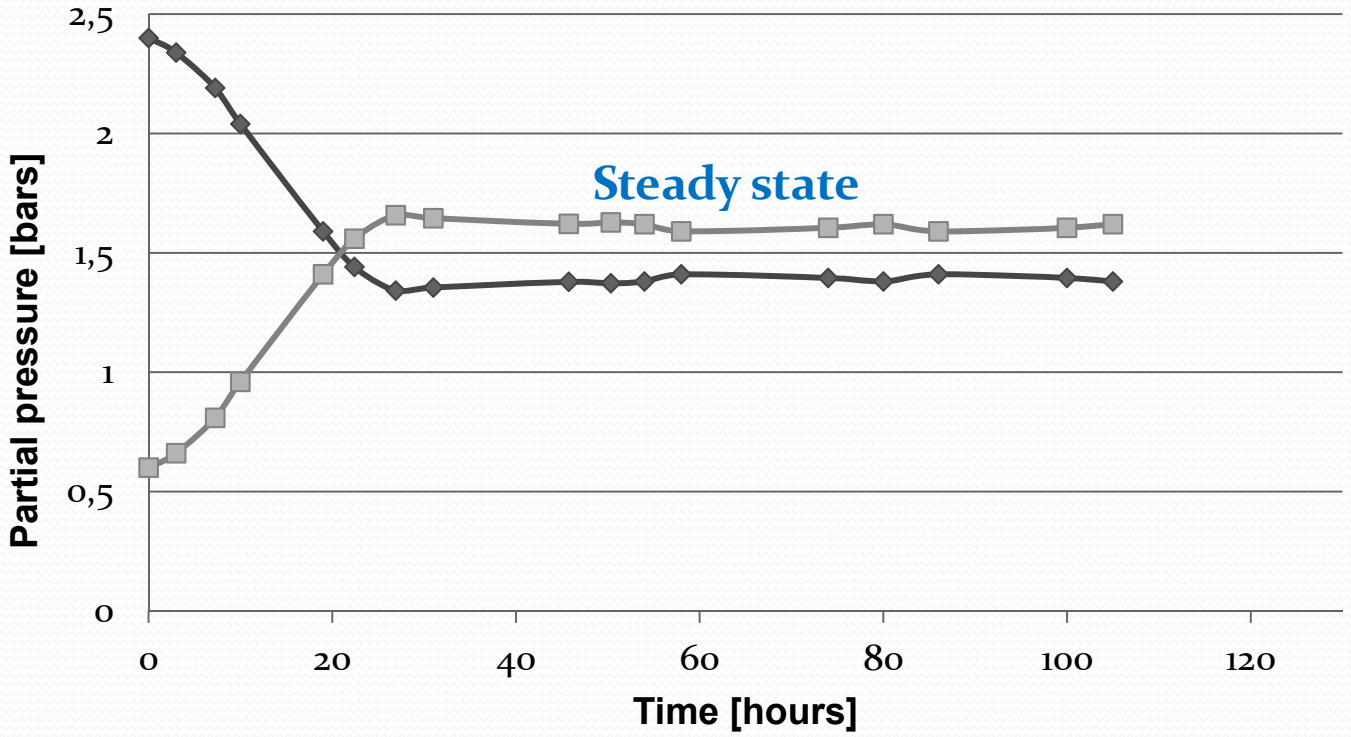
- High mass transfer

- No N_2 accumulation under continuous operation



Proof of concept with GC analysis

Reaching gas-liquid equilibrium



Influent: 25 mg N/L
Effluent: 10 mg N/L
Total pressure: 3 bars

H2 utilization > 90%
Max. denitrification rate ≈ 9 g N/($L_{reactor}$·d)

Summary

- Main features of the pressurized reactor:
  - High H_2 utilization (>90%)
  - Safe operation
  - High denitrification rates (up to 9 gN/[$L_{reactor}$ x day])
- Competitive alternative to existing technologies due to simplicity and higher rates.
- Future improvements: increasing H_2 utilization, treatment of water with high nitrate concentration

Thank you!