FACULTY OF BIOSCIENCE ENGINEERING

CMET
Center for Microbial Ecology and Technology

BIO-ELECTROCHEMICAL PRE-TREATMENT AND MEMBRANE AERATION TO INTENSIFY FULL NITROGEN RECOVERY FOR SPACEFLIGHT URINE NITRIFICATION

Jolien De Paepe, Siegfried E. Vlaeminck, Korneel Rabaey, Francesc Gòdia, Peter Clauwaert

1st Joint AgroSpace-MELiSSA workshop, Rome, 16th of May 2018

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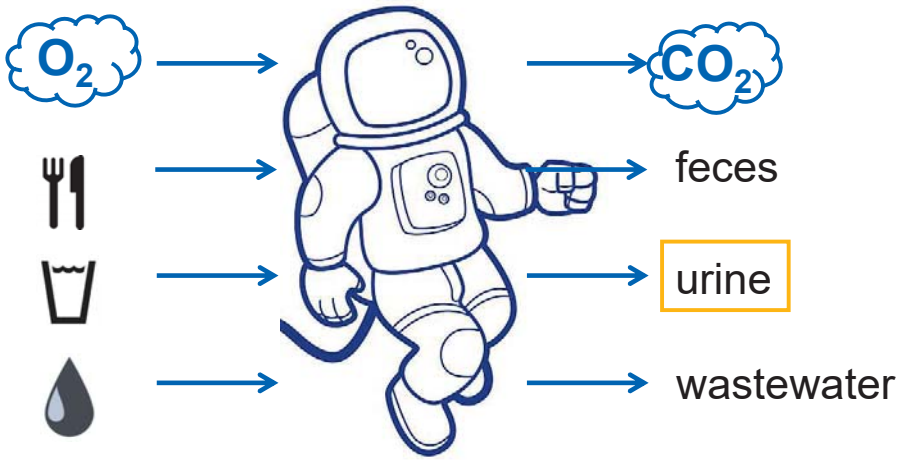
URINE IS AN IMPORTANT NUTRIENT SINK IN A LSS



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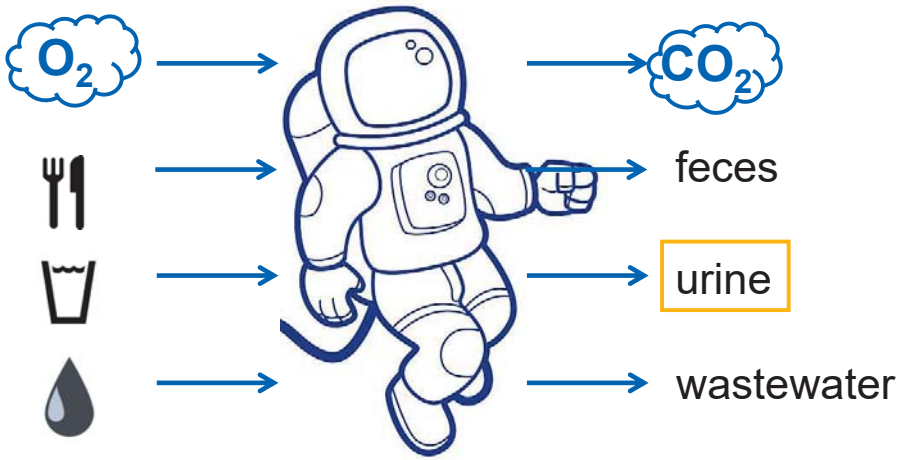
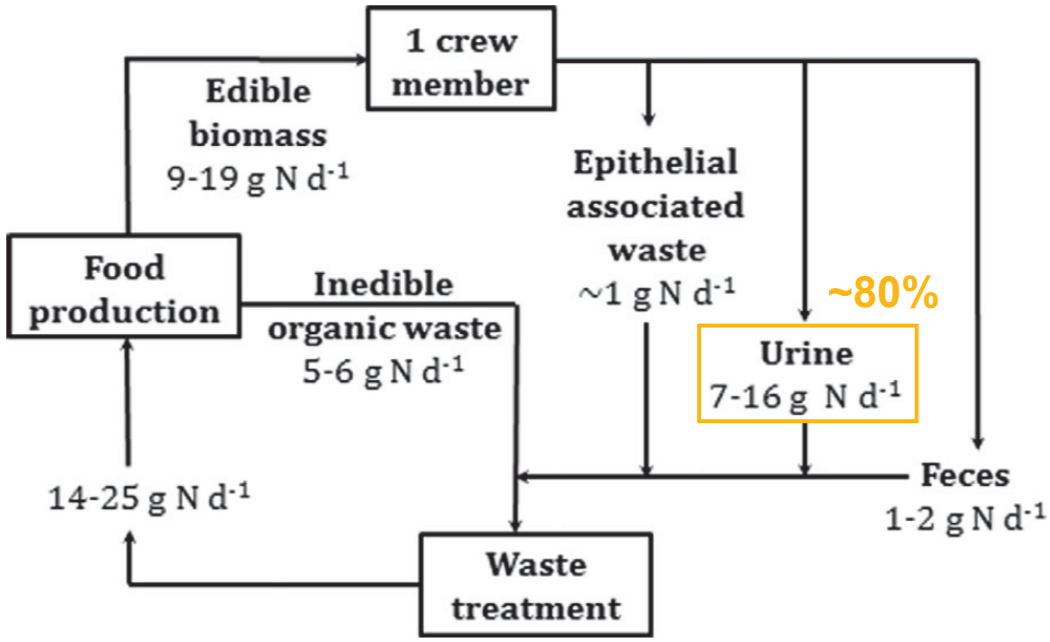
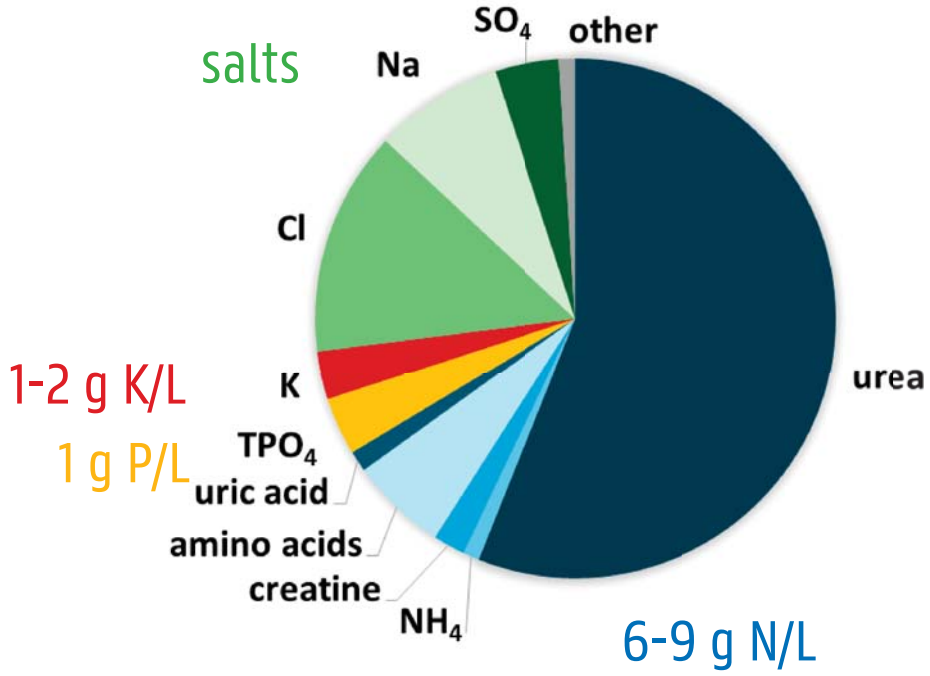




Clauwaert et al. (2017) Progress in Aerospace Sciences (91)

URINE, AN OPTIMAL PLANT FERTILIZER?



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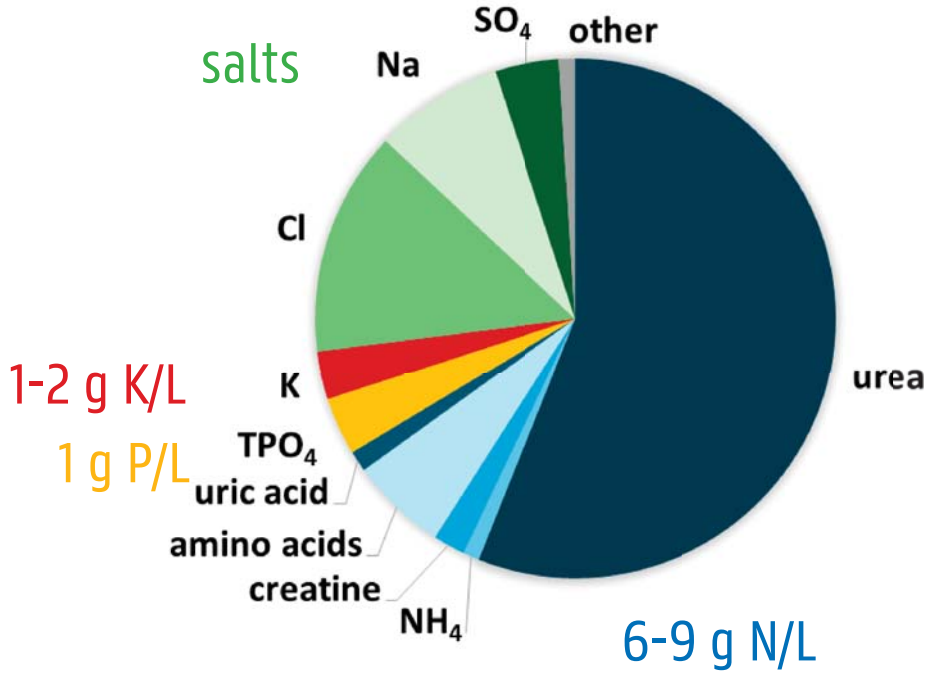

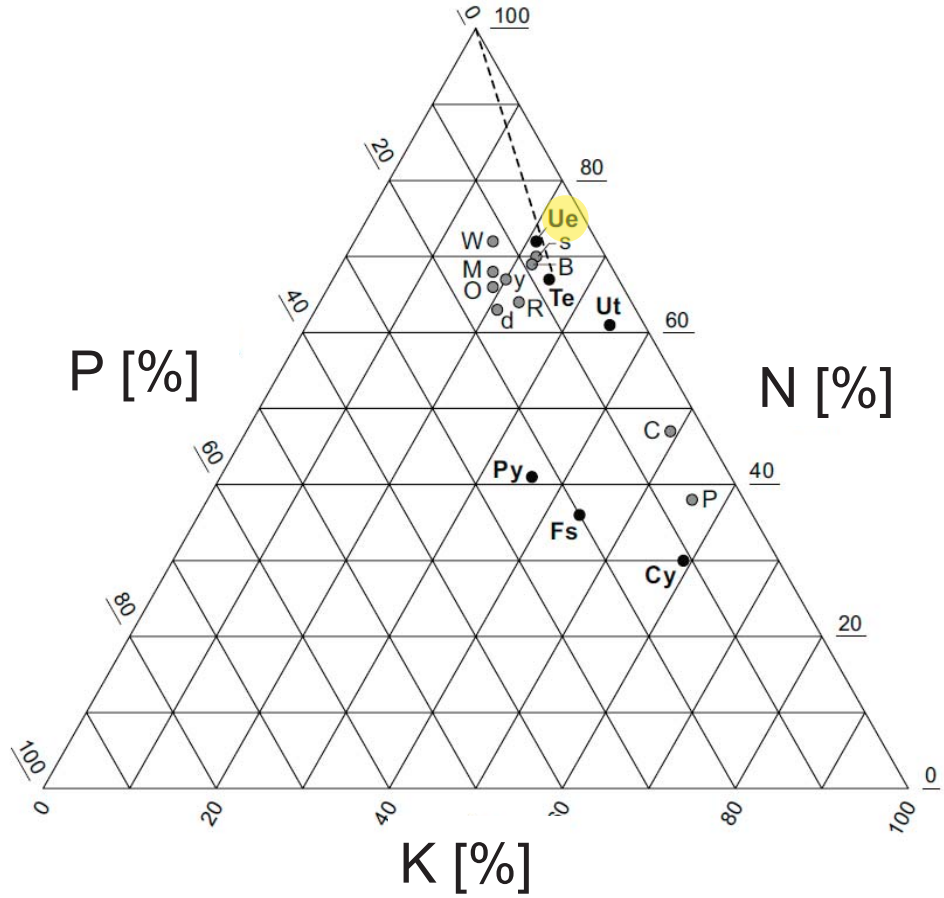

Larsen, Udert and Lienert (2013). IWA publishing

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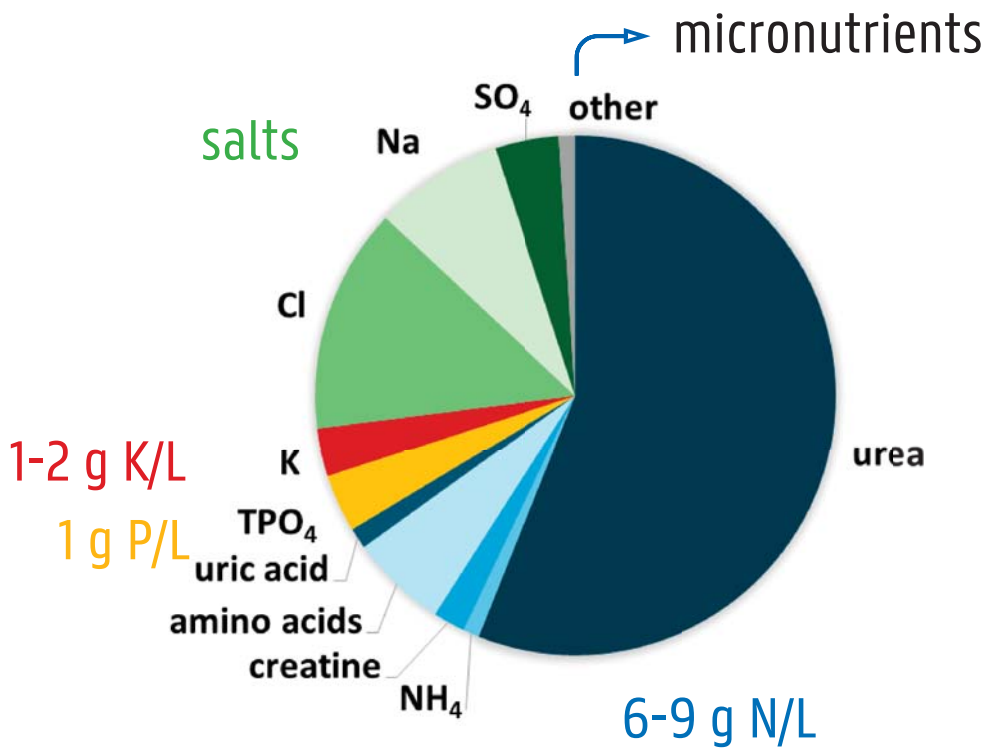

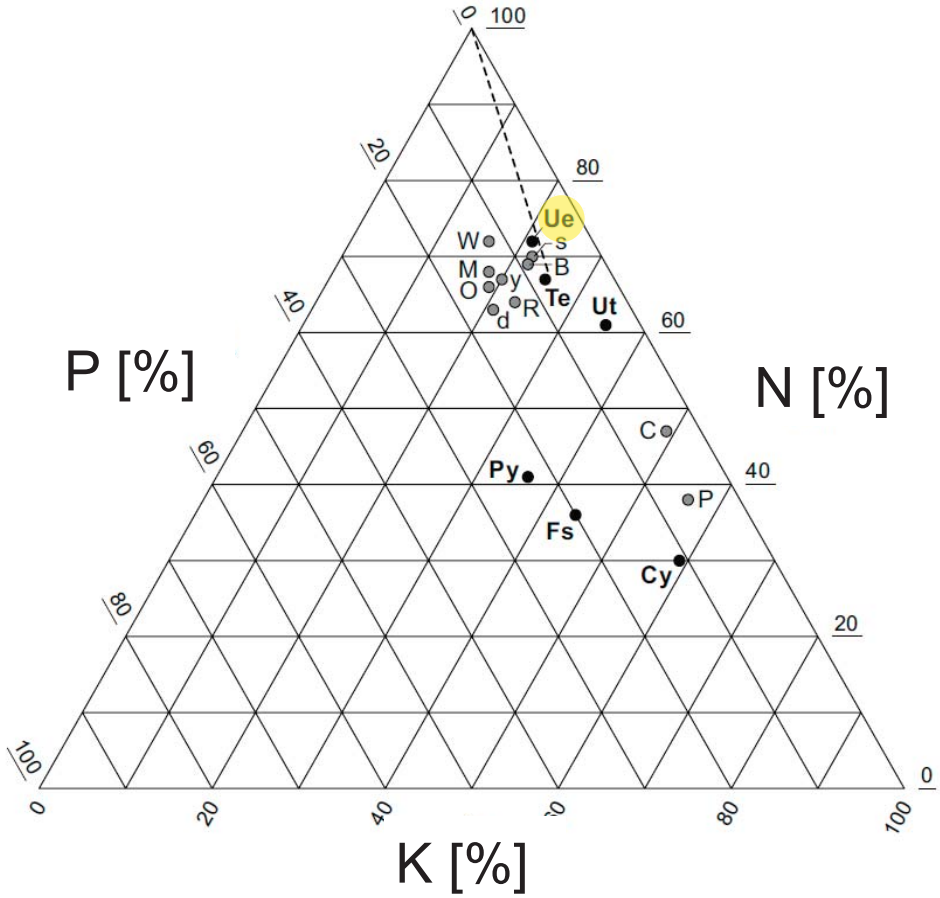

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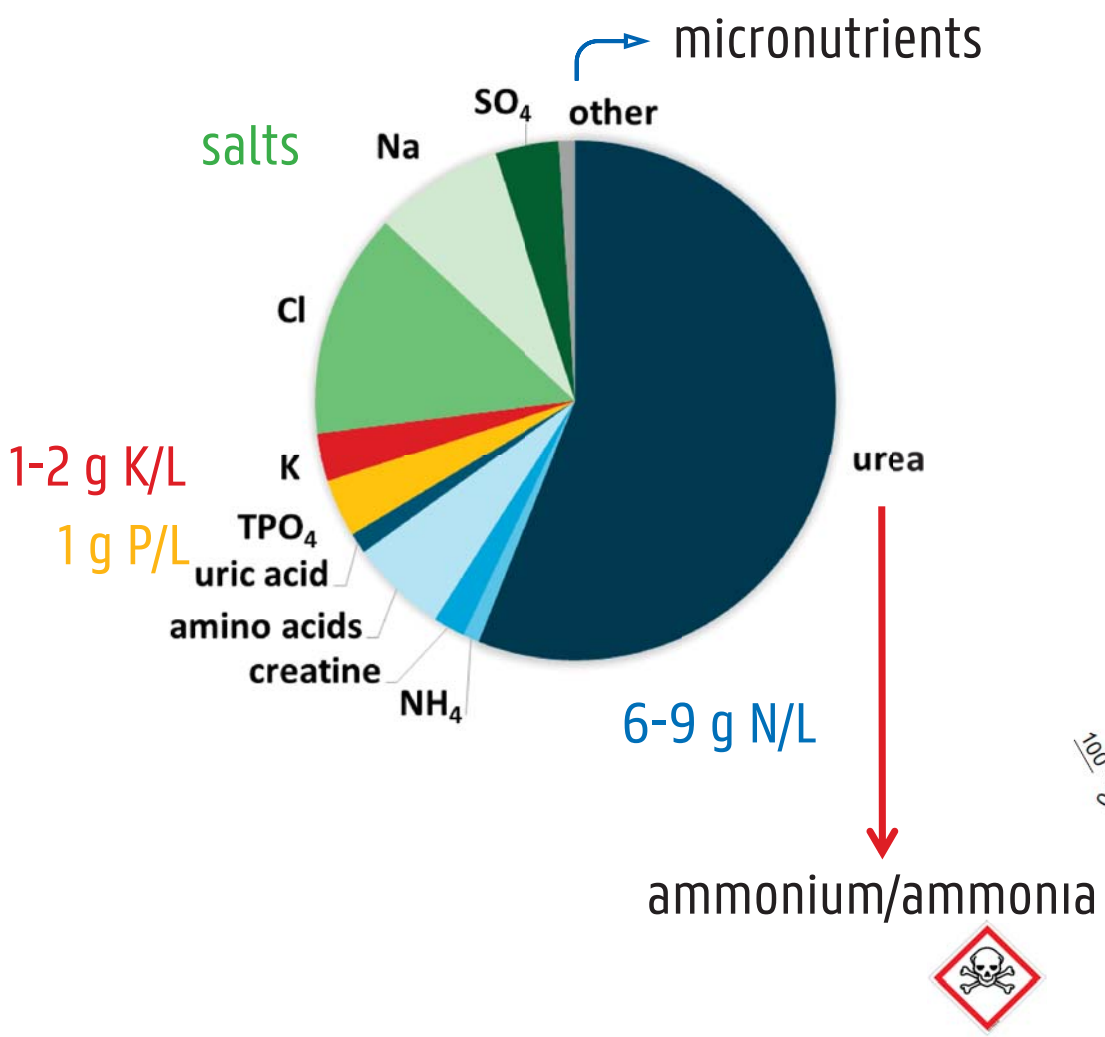

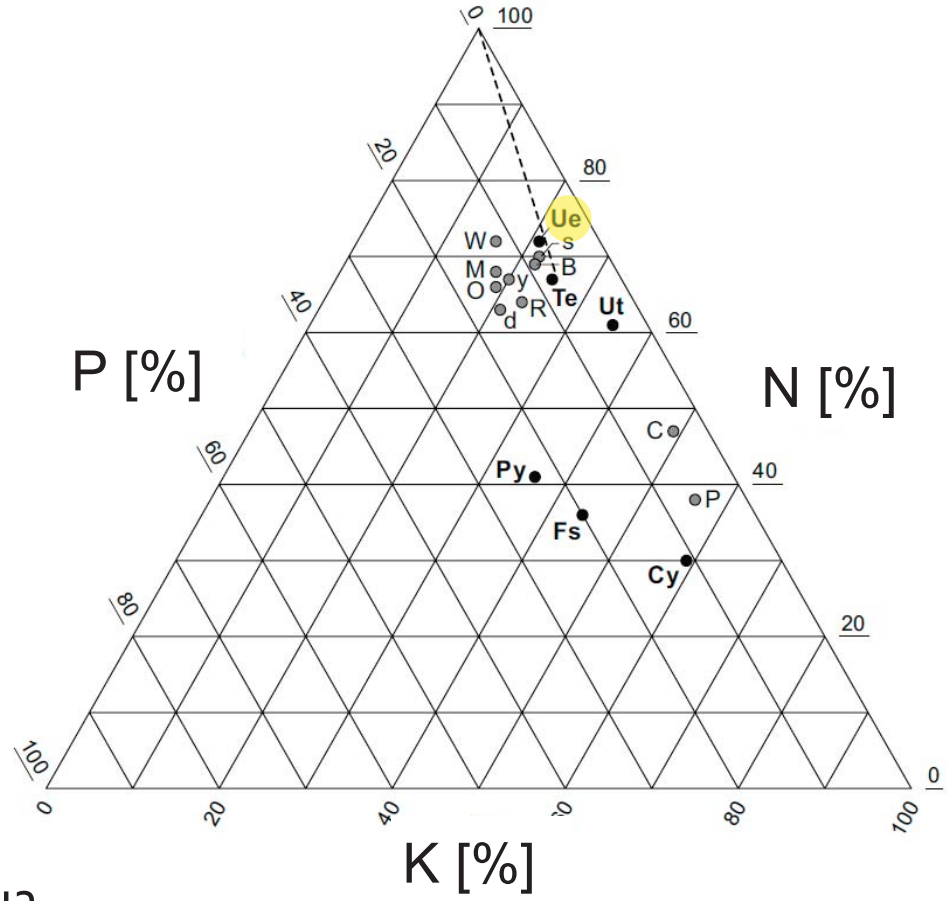

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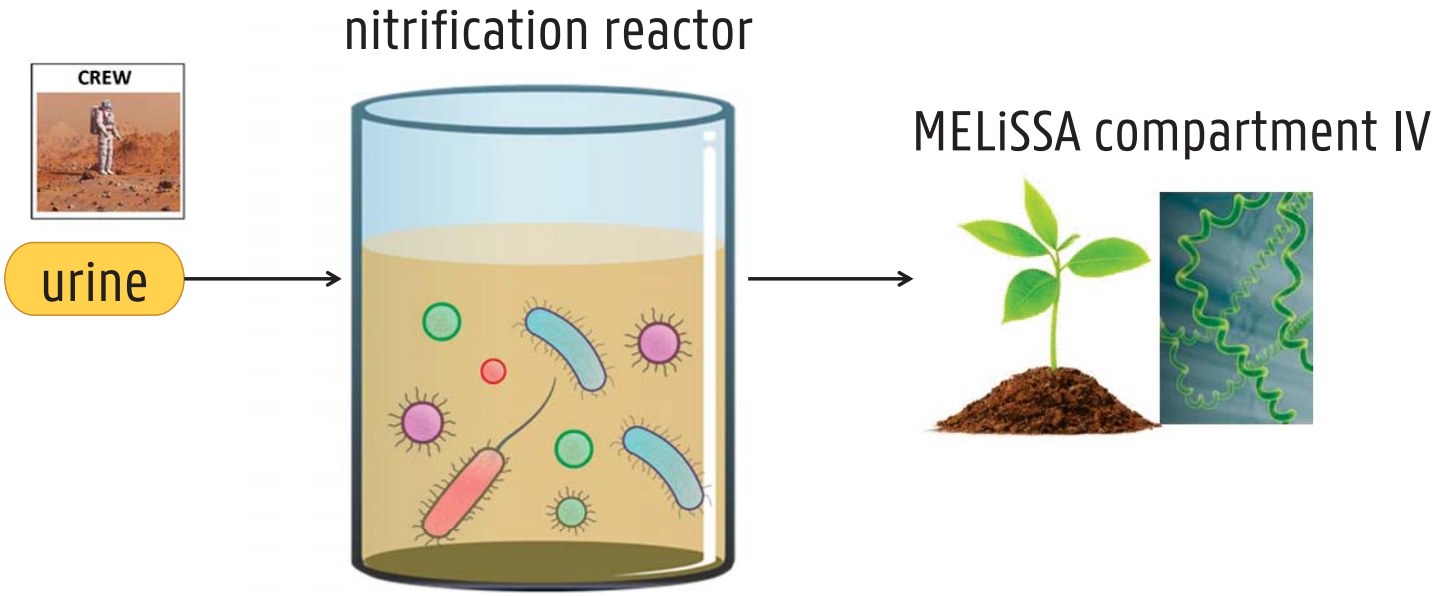
NITRIFICATION TO STABILIZE URINE



urea-N → ammonium-N → nitrate-N

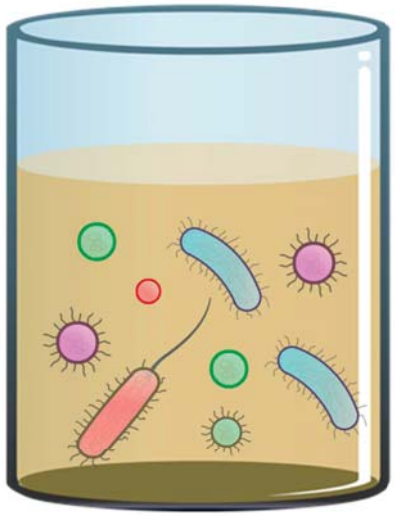
- non-volatile and non-toxic (⇔ NH_4^+)
- preferred N source of plants

COD → CO_2

NITRIFICATION TO STABILIZE URINE

nitrification reactor

urine



MELiSSA compartment IV

urea-N → ammonium-N → nitrate-N

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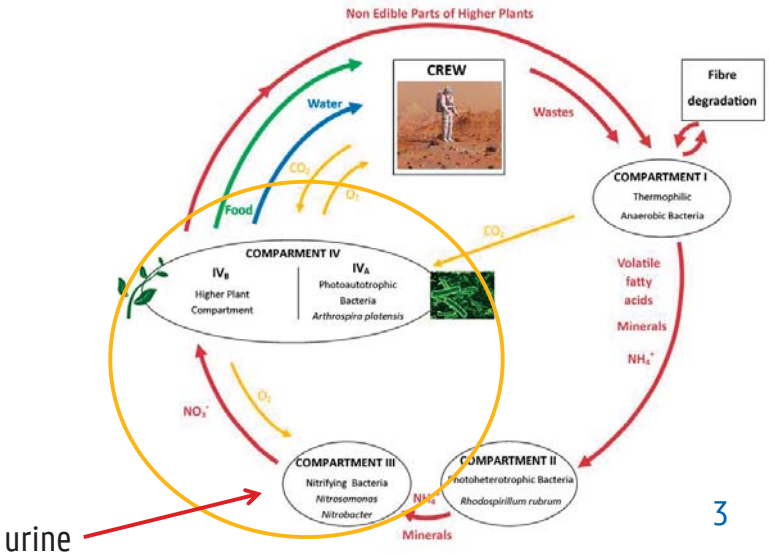
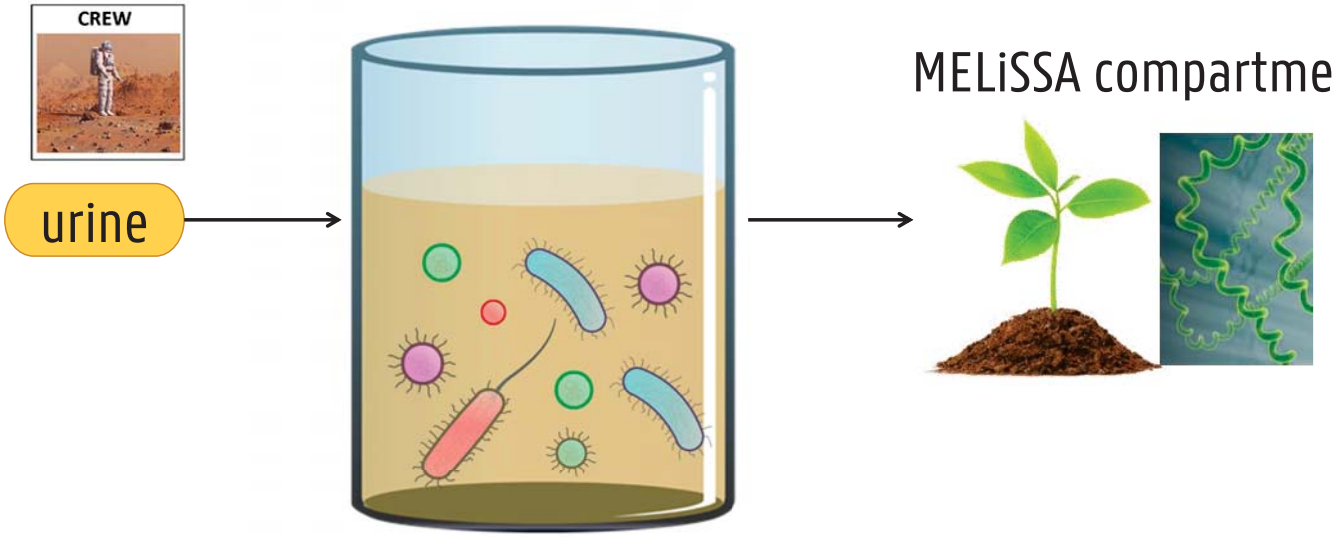


OXYGEN DEMAND FOR NITRIFICATION AND COD OXIDATION

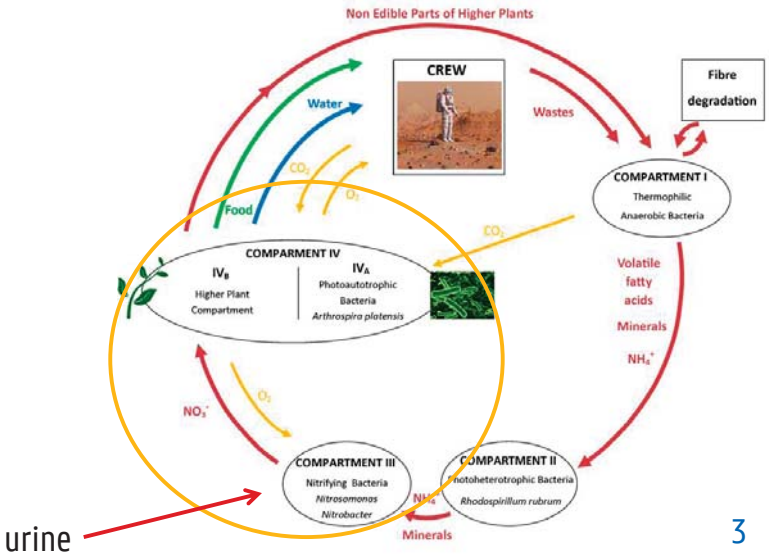
nitrification reactor



$$CO(NH_2)_2 + 4\ O_2 \rightarrow 2\ NO_3^- + HCO_3^- + 3\ H^+$$

$$COD + O_2 \rightarrow CO_2$$

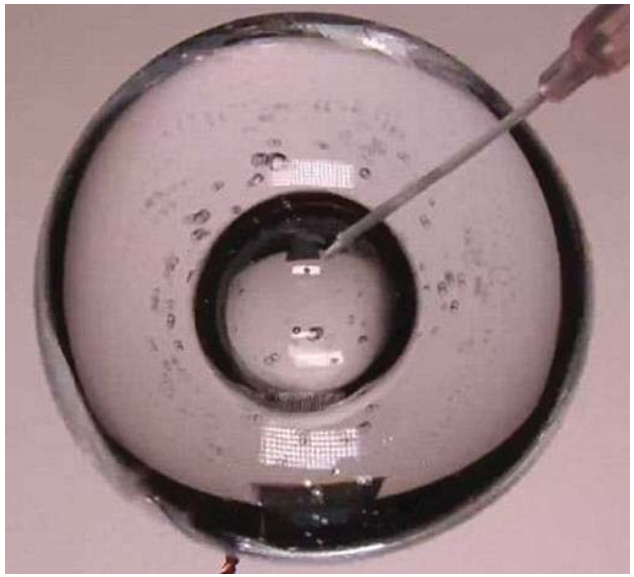
~40-50 g O_2/L_{urine}

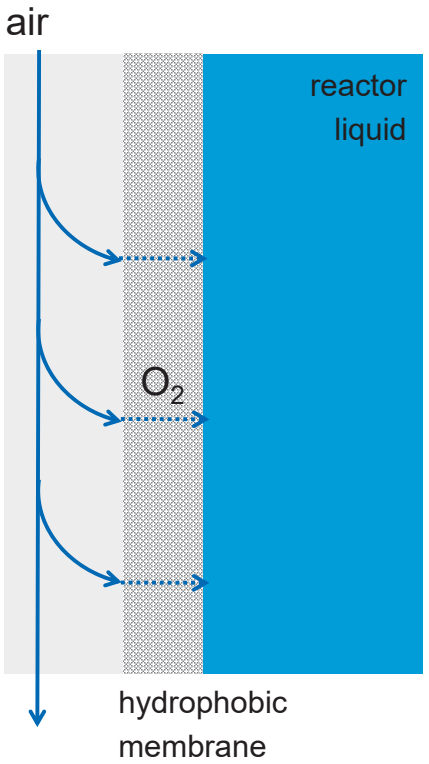


BUBBLE LESS AERATION

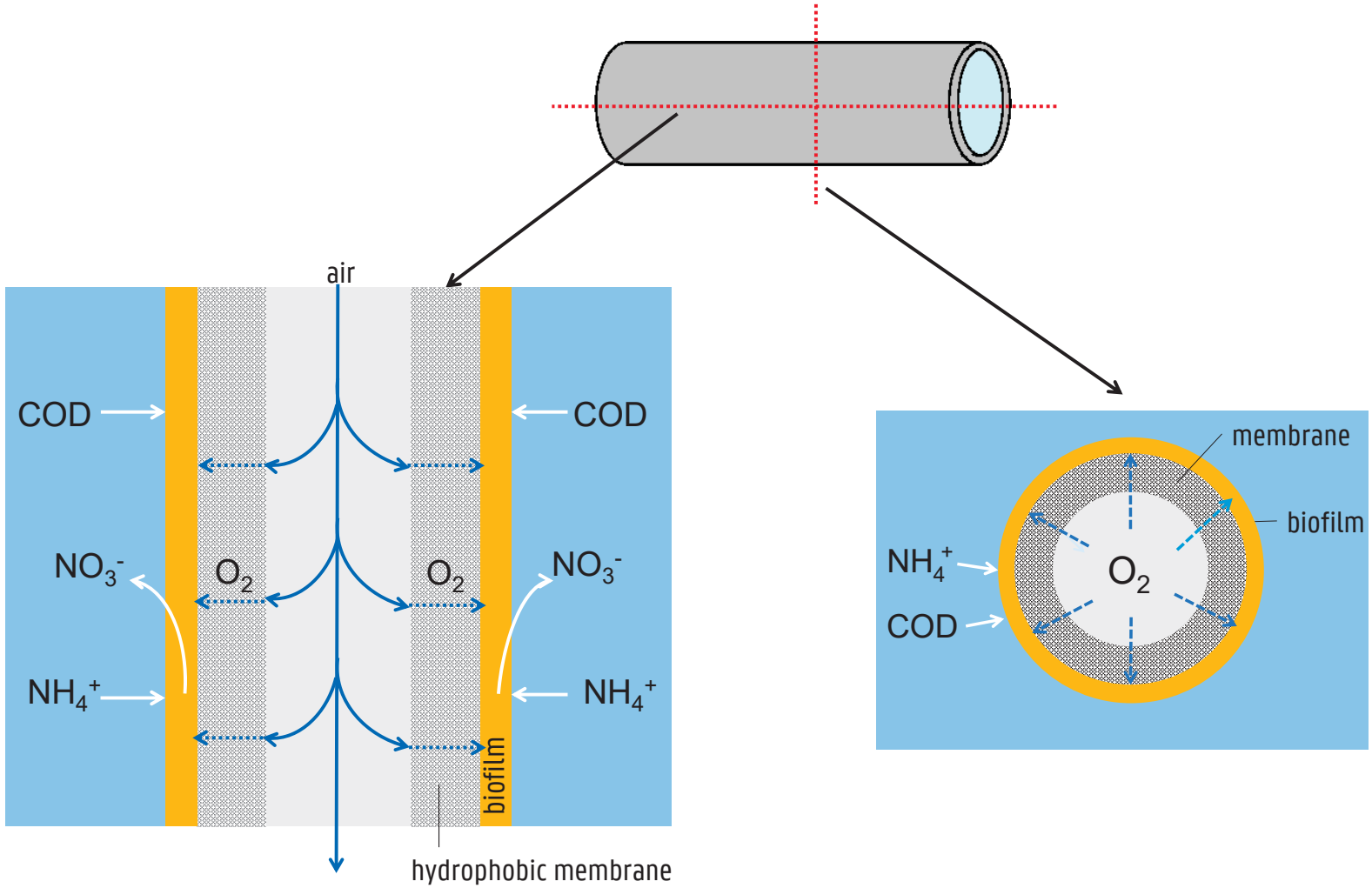
Earth: bubble aeration

Space: membrane aeration

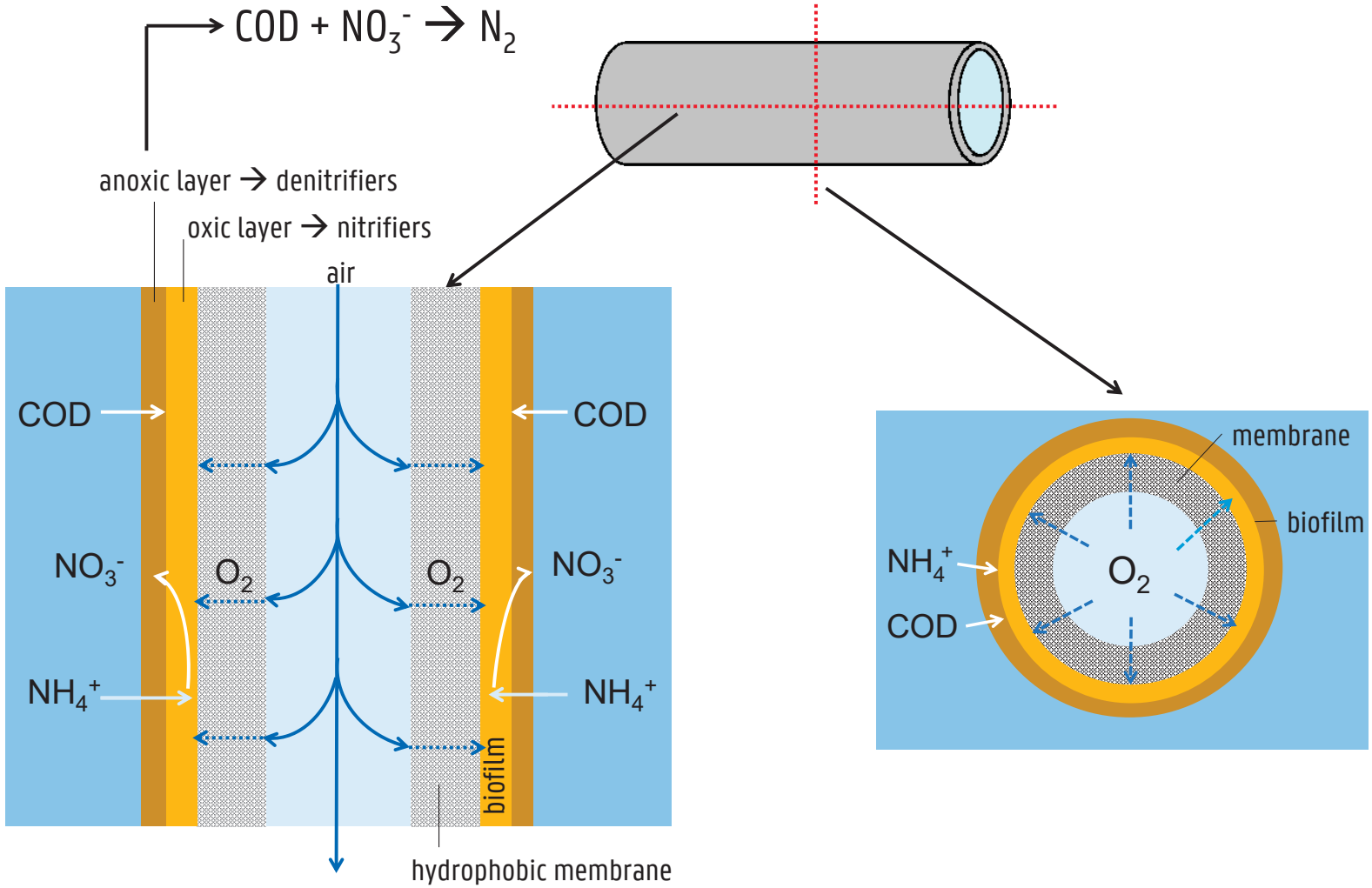




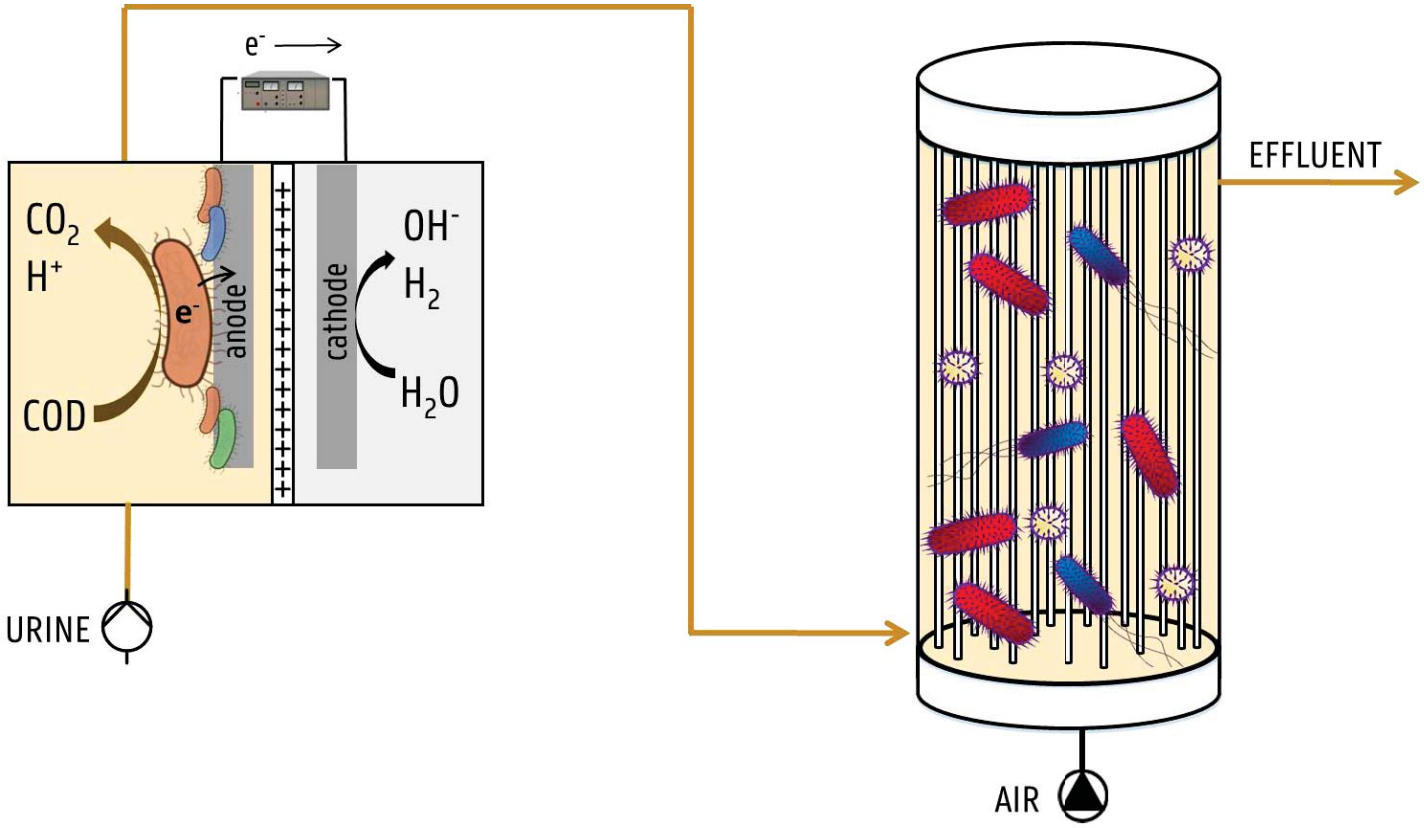
HOLLOW-FIBER MEMBRANE AERATED BIOFILM REACTOR



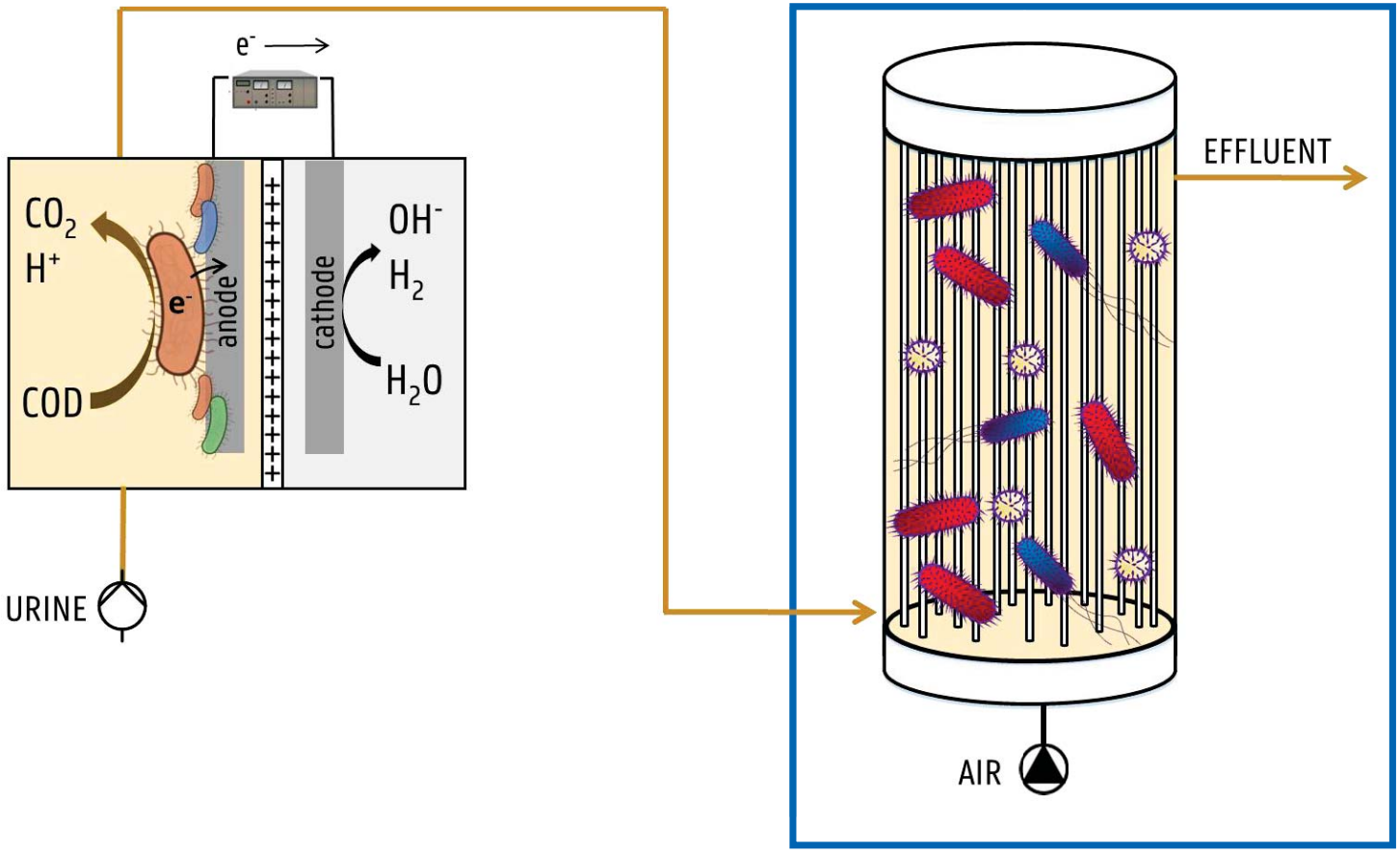
RISK FOR DENITRIFICATION



2-STAGE MICROGRAVITY COMPATIBLE URINE NITRIFICATION REACTOR

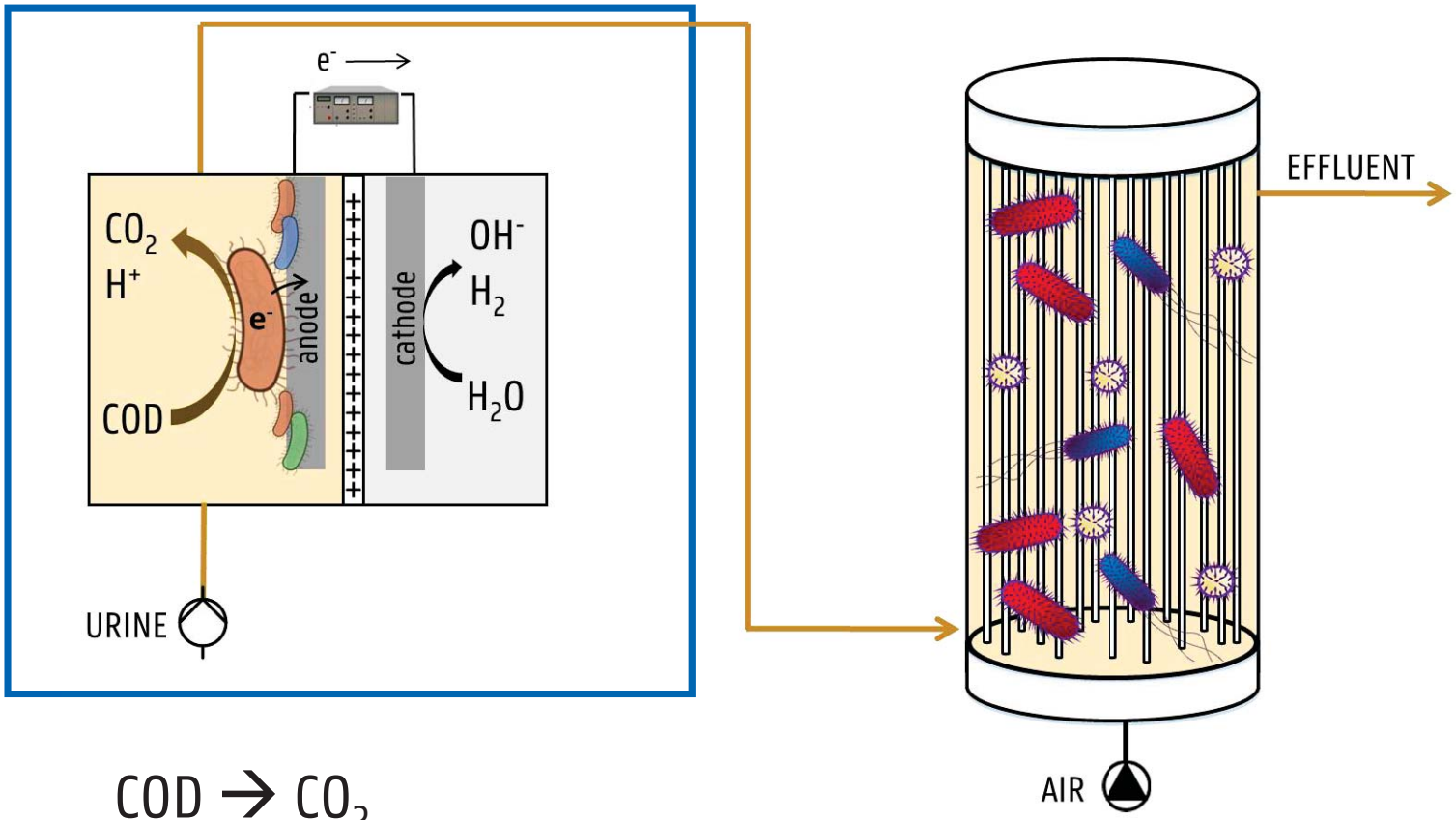


MEMBRANE AERATED BIOFILM REACTOR FOR NITRIFICATION



$$NH_4 + 2\,O_2 \rightarrow NO_3^- + H_2O + 2\,H^+$$

BIO-ELECTROCHEMICAL SYSTEM (BES) TO PREVENT DENITRIFICATION



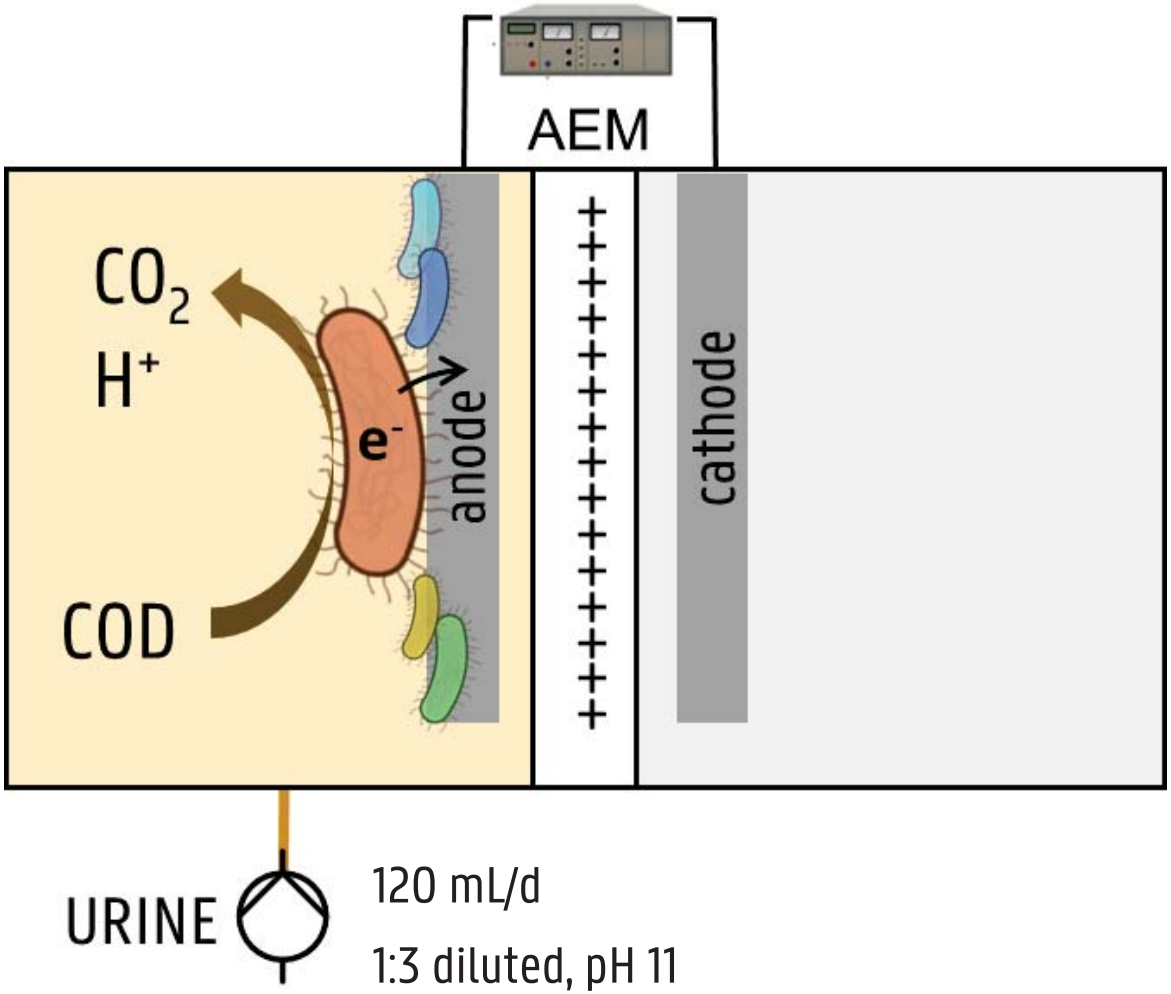
COD → CO_2

urea → ammonium

ELECTROACTIVE BACTERIA OXIDIZE COD

COD=electron donor

Anode=electron acceptor

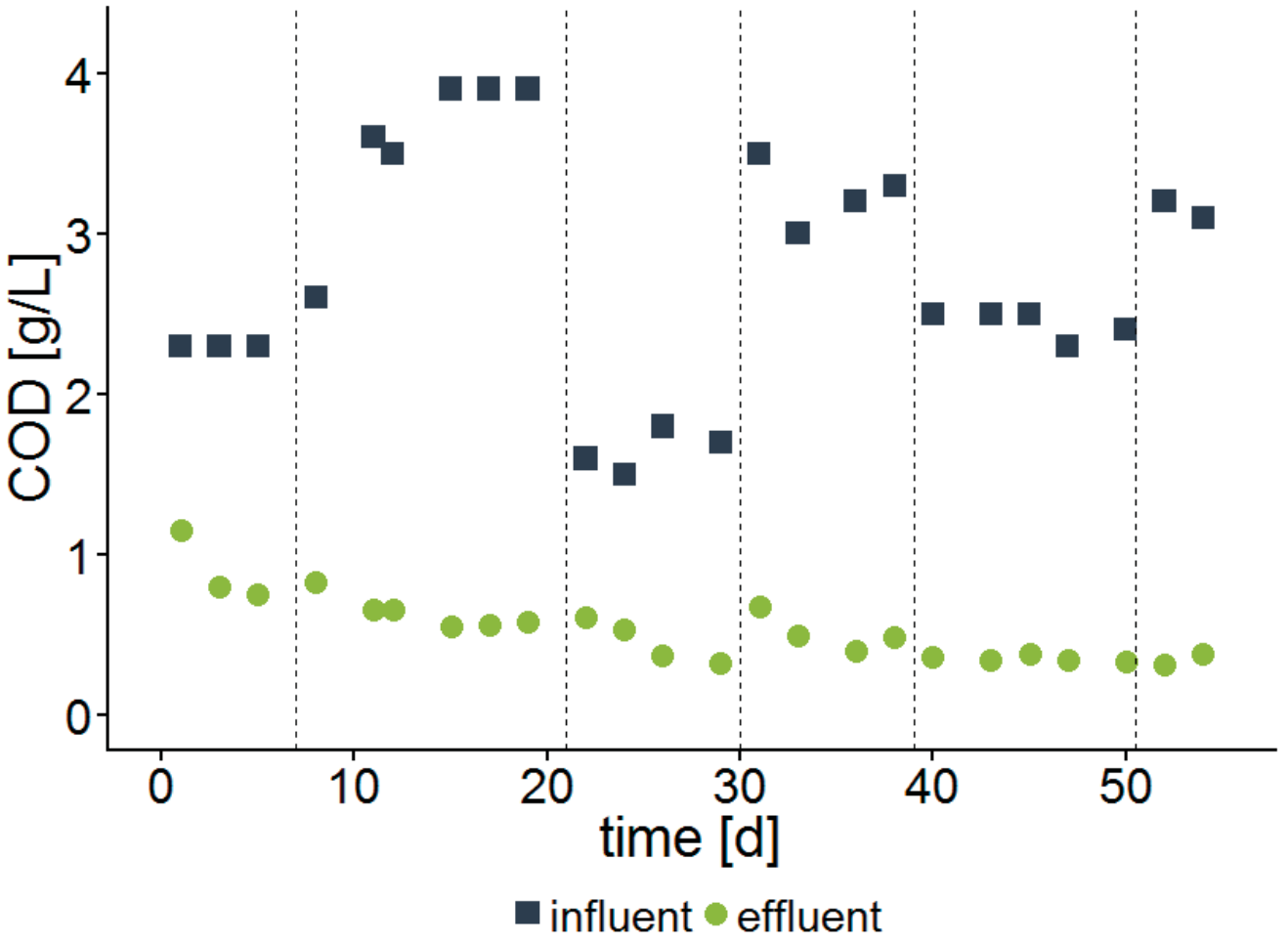


~85% COD REMOVAL

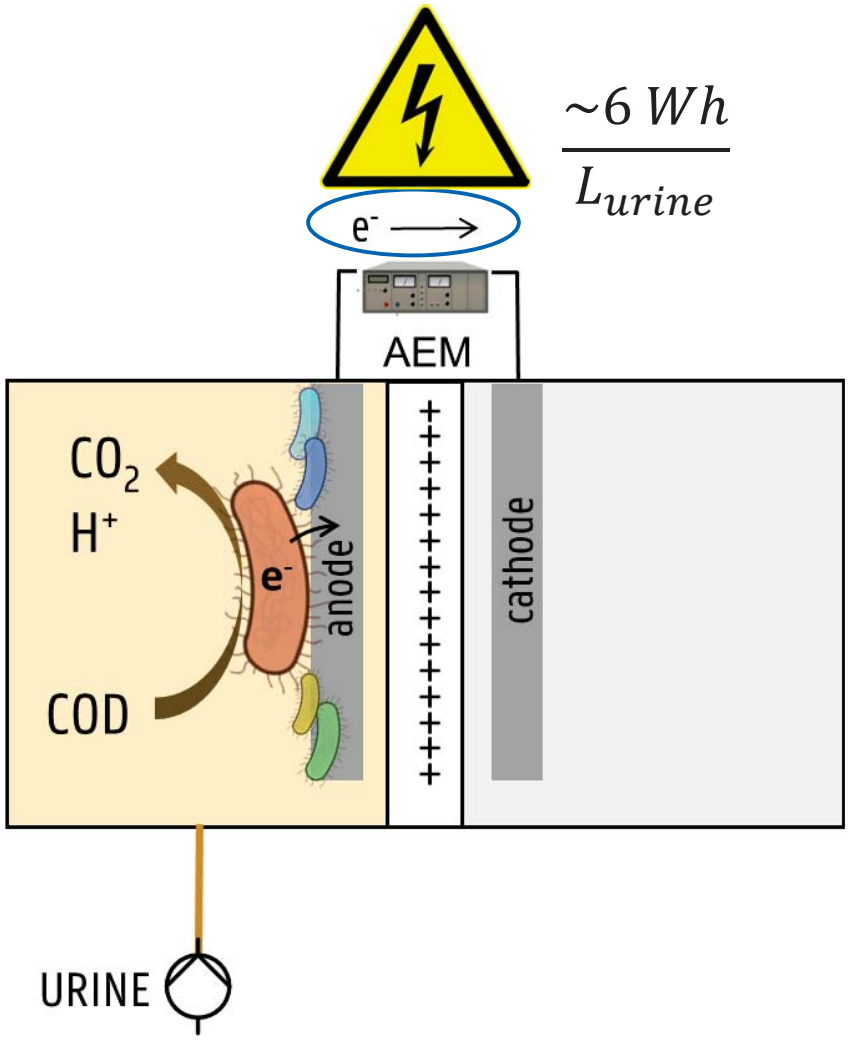
120 mL/d, 2-4 g COD/L

→ 340 mg COD/d

→ 810 mg COD/L/d

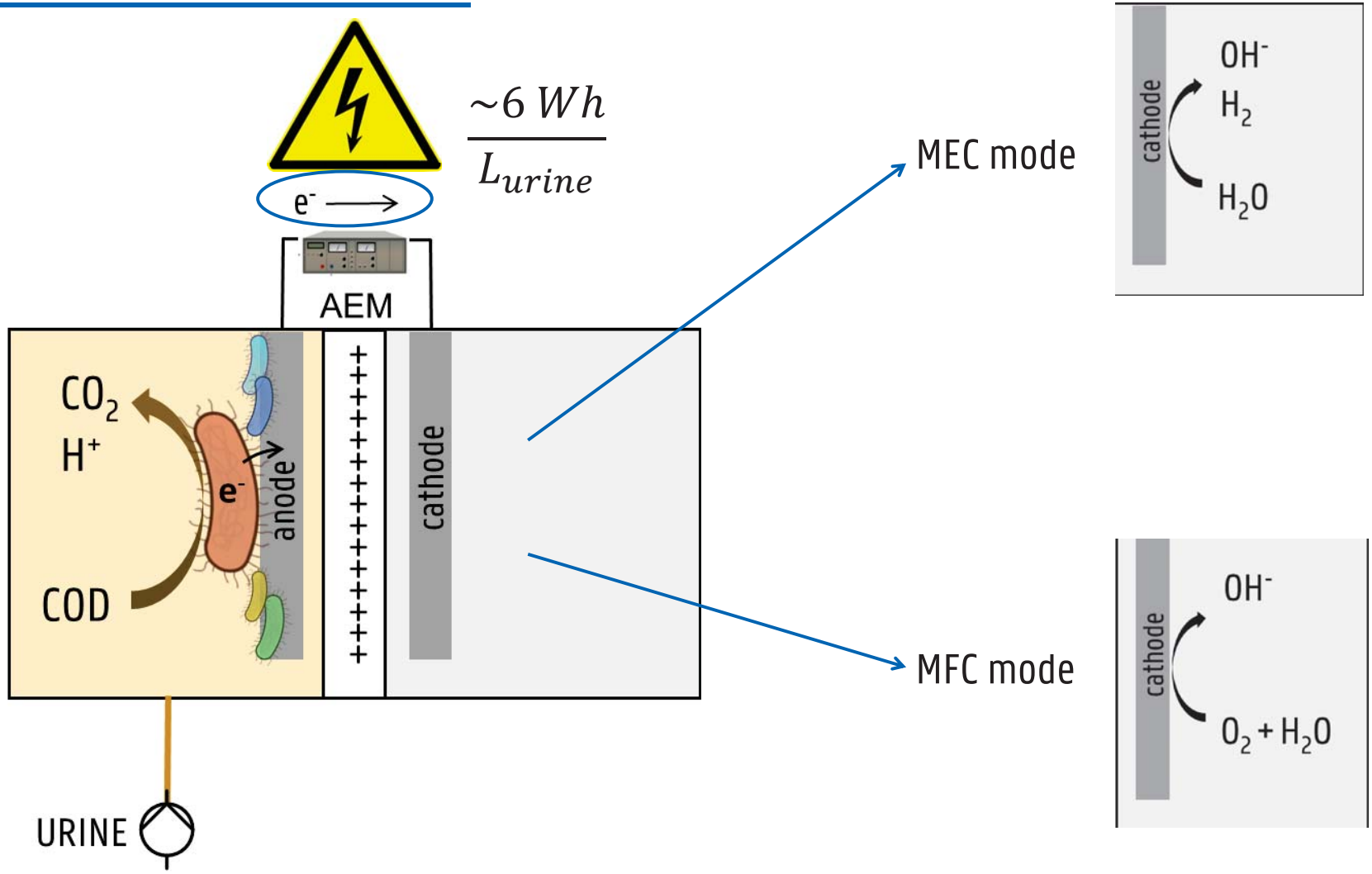


CURRENT PRODUCTION

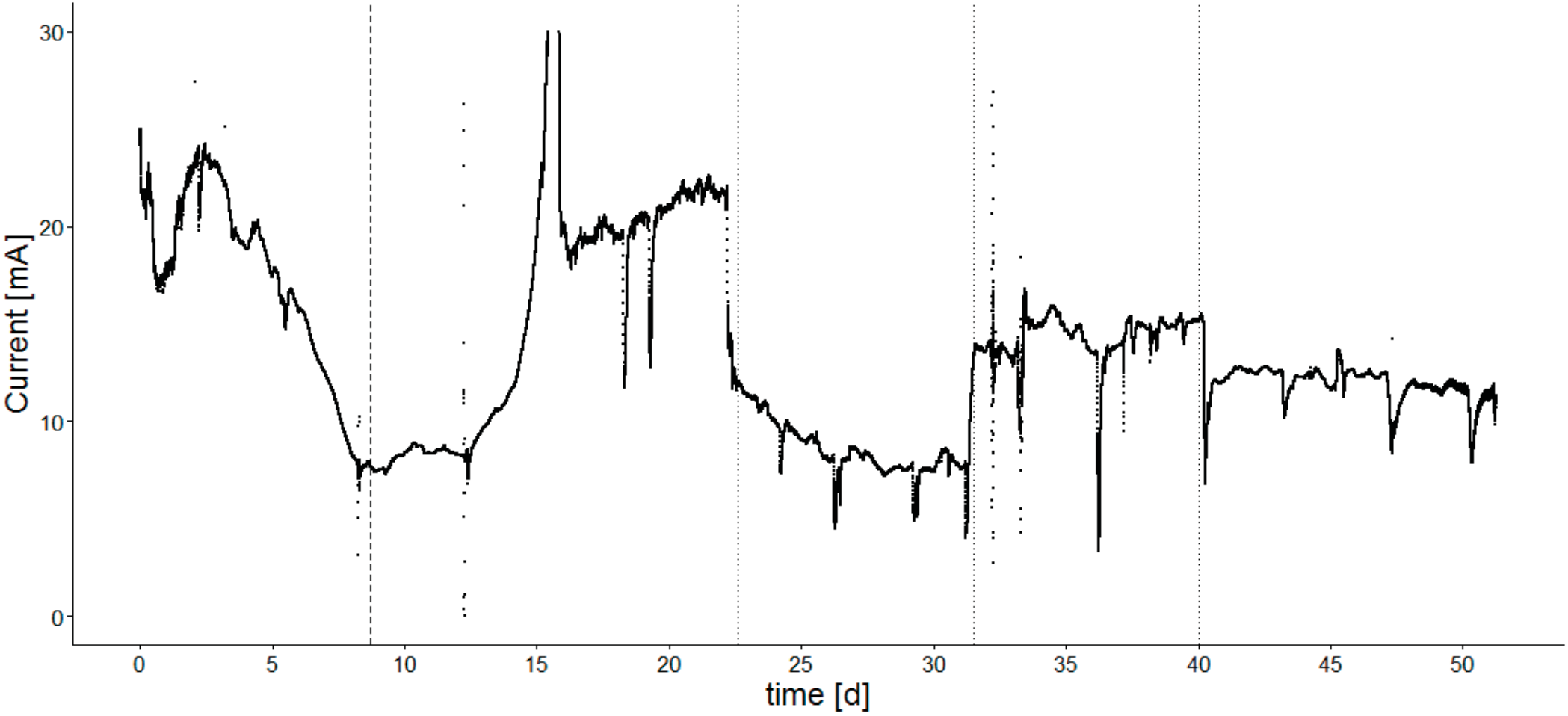


$$\frac{\sim 6\ Wh}{L_{urine}}$$

CURRENT PRODUCTION

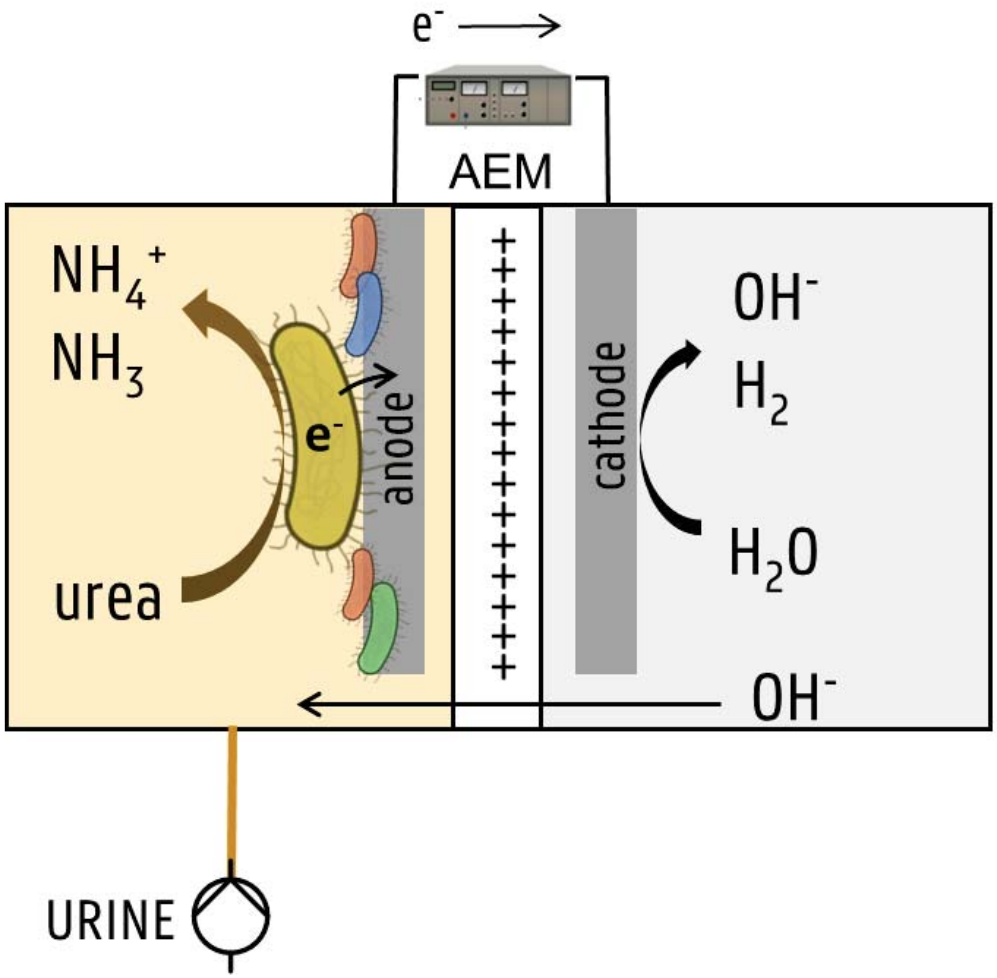


CURRENT PRODUCTION



anode potential: -250 mV

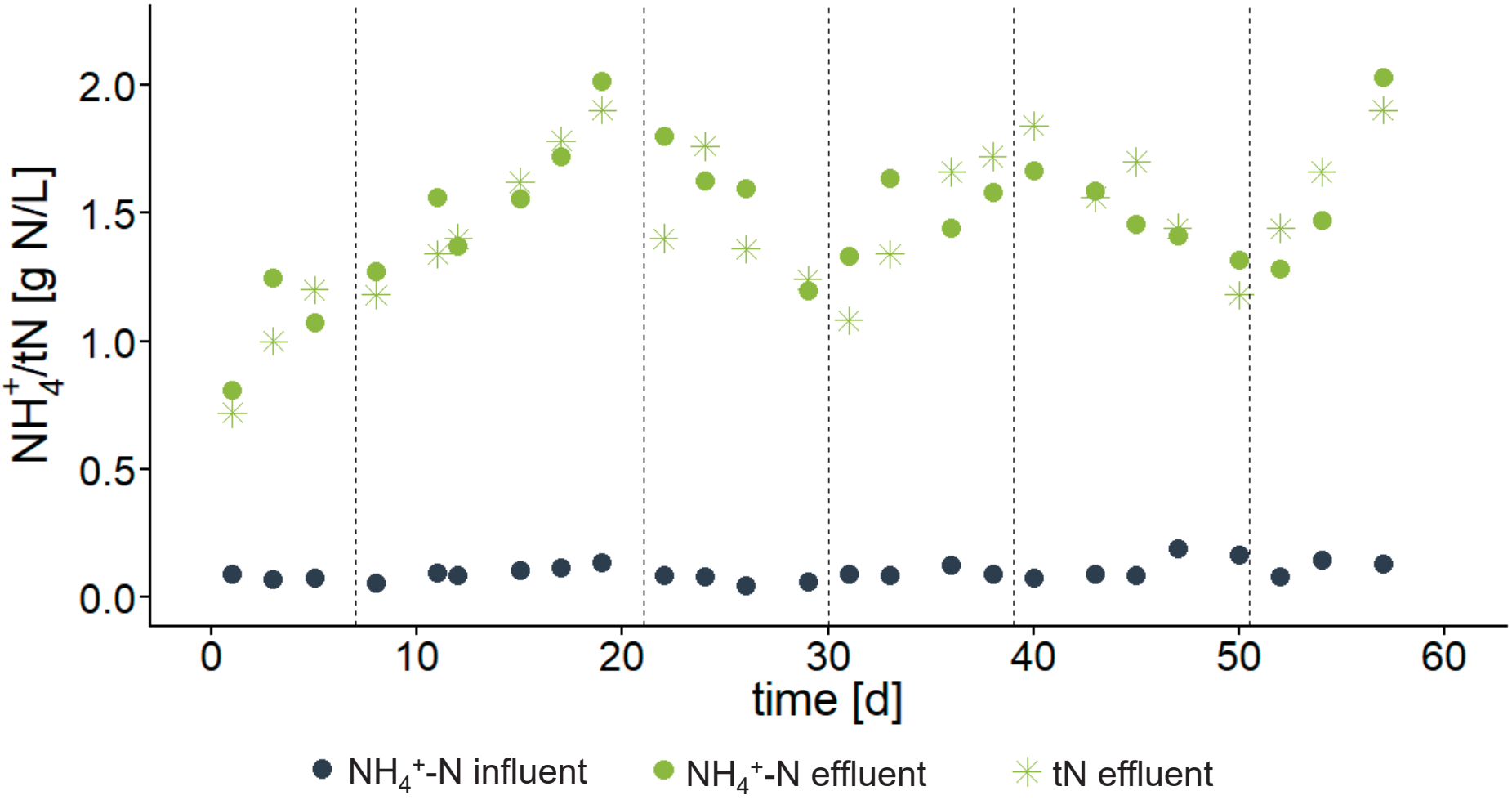
UREA HYDROLYSIS



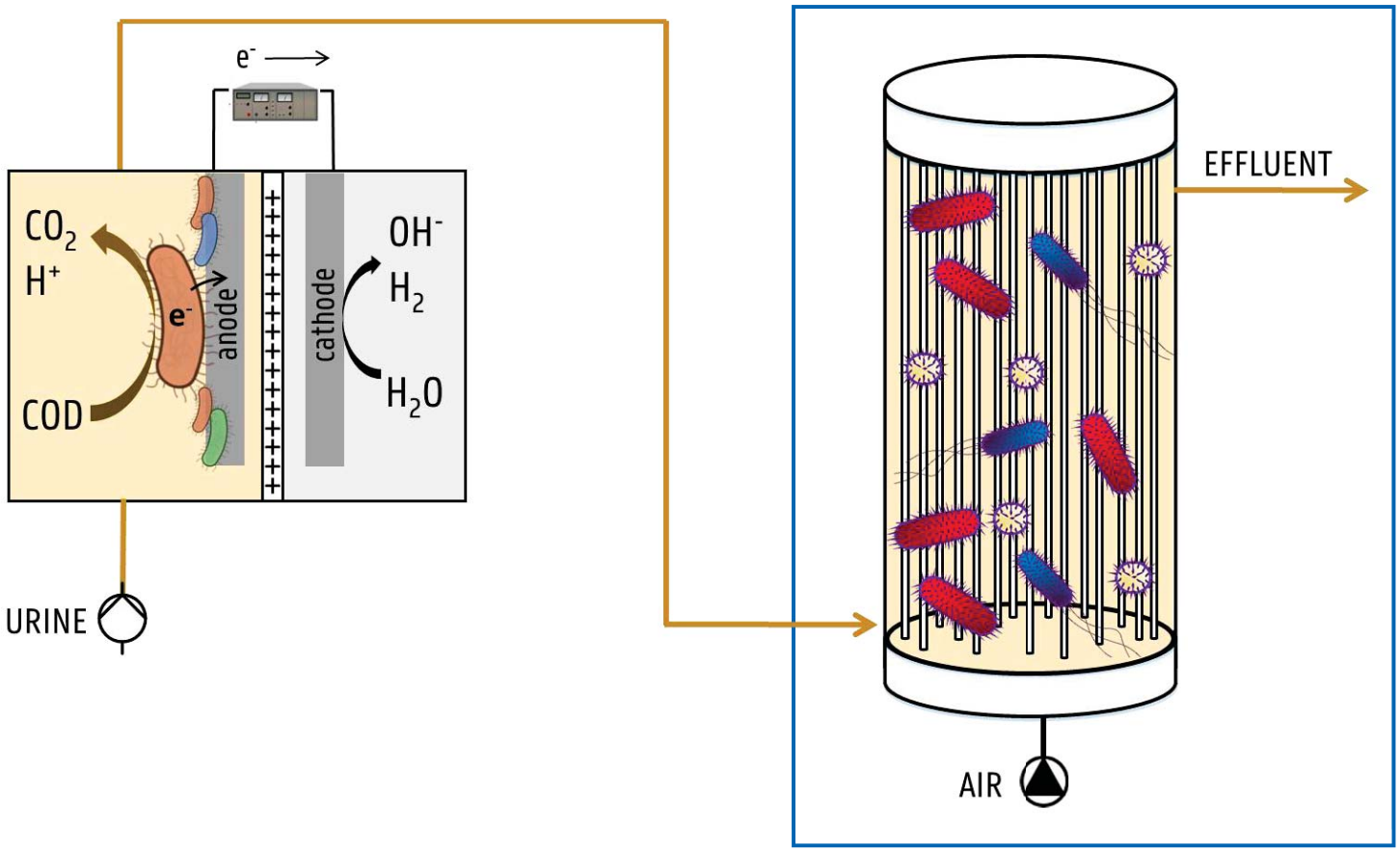
urea → ammonium → nitrite → nitrate

BES MABR

~100% UREA HYDROLYSIS

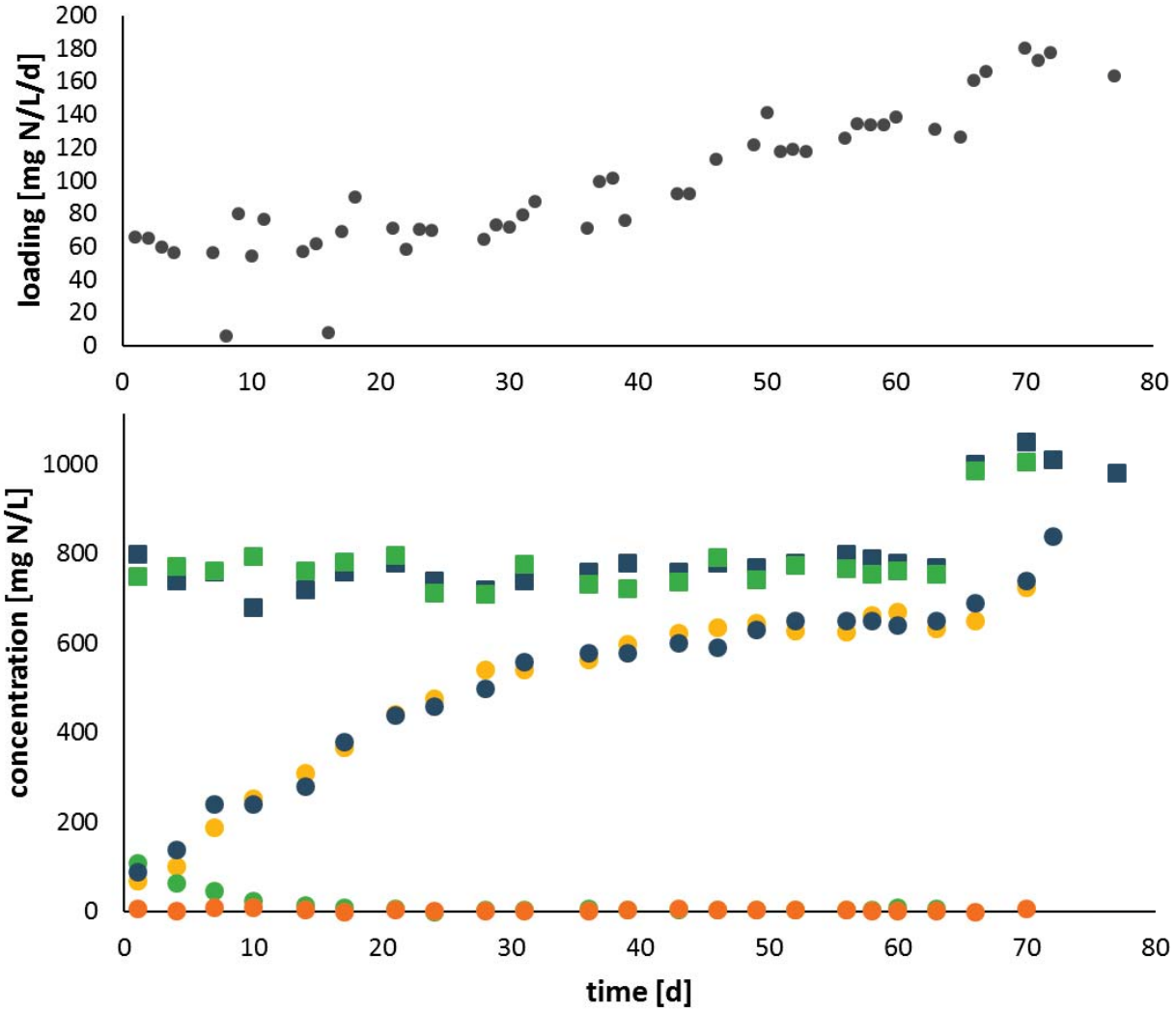


MEMBRANE AERATED BIOFILM REACTOR FOR NITRIFICATION

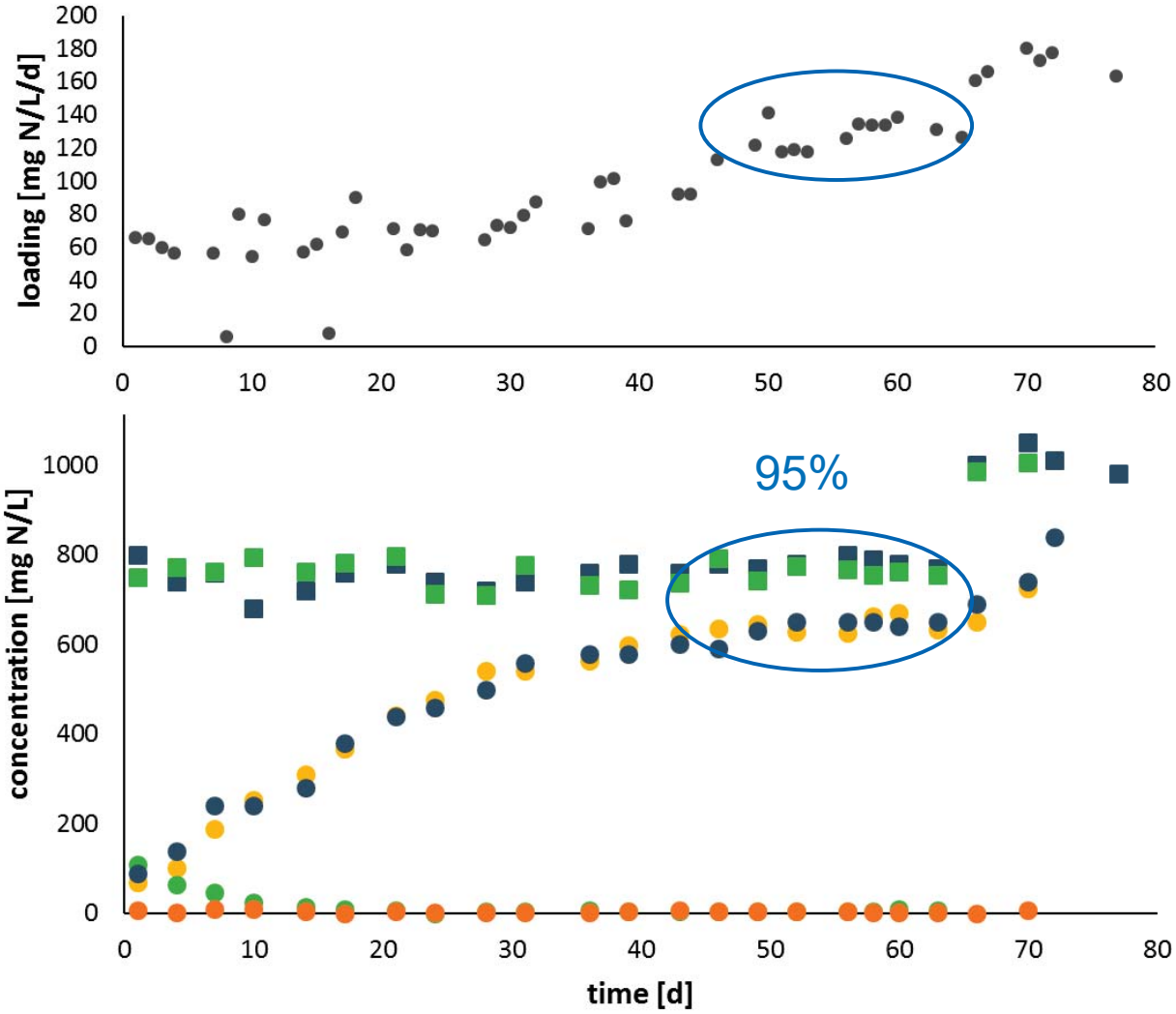


$$NH_4 + 2\,O_2 \rightarrow NO_3^- + H_2O + 2\,H^+$$

100% NITRIFICATION



100% NITRIFICATION



85 mg N/d

130 mg N/L/d

tN influent

NH_4-N influent

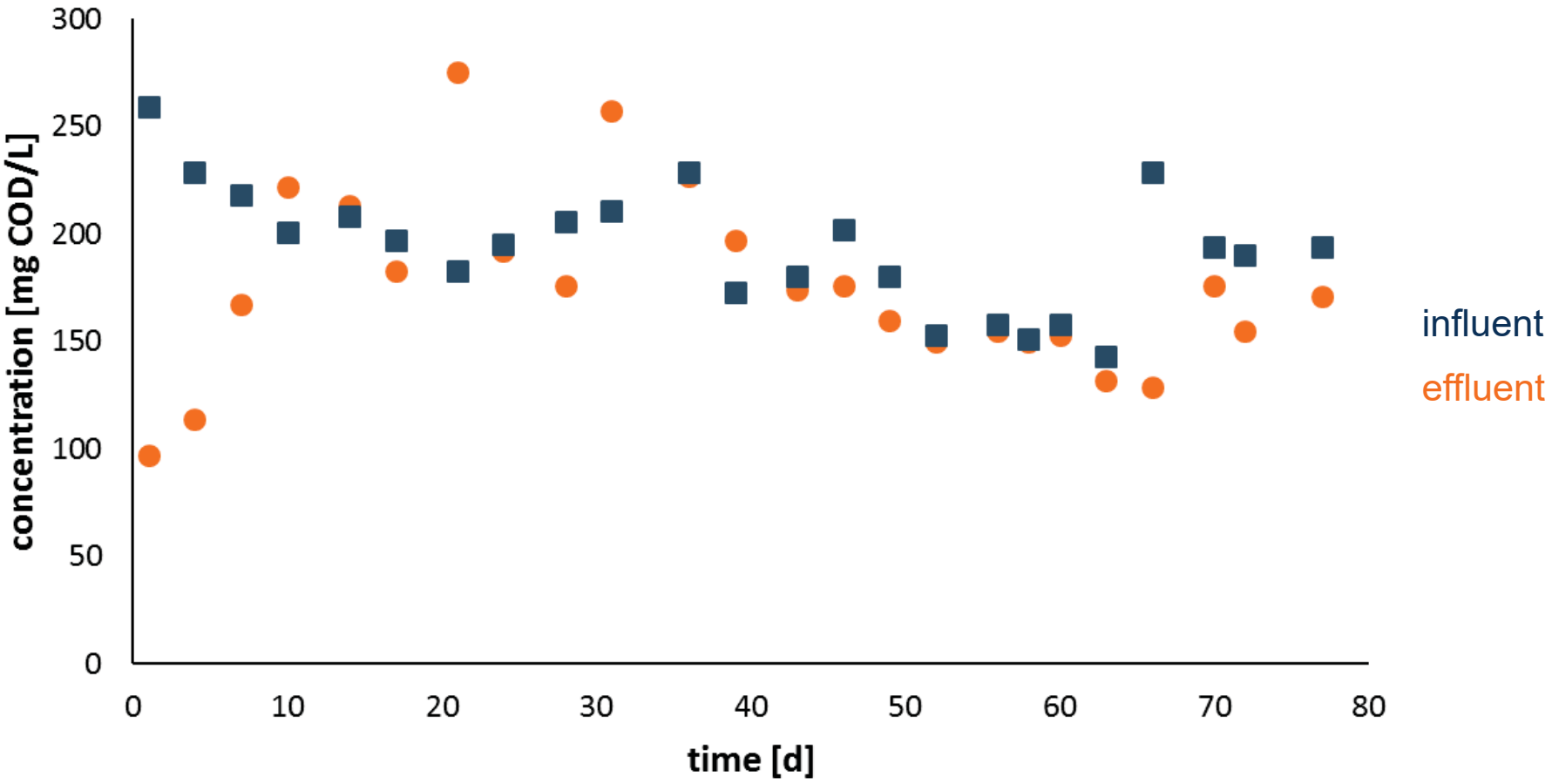
tN effluent

NO_3-N effluent

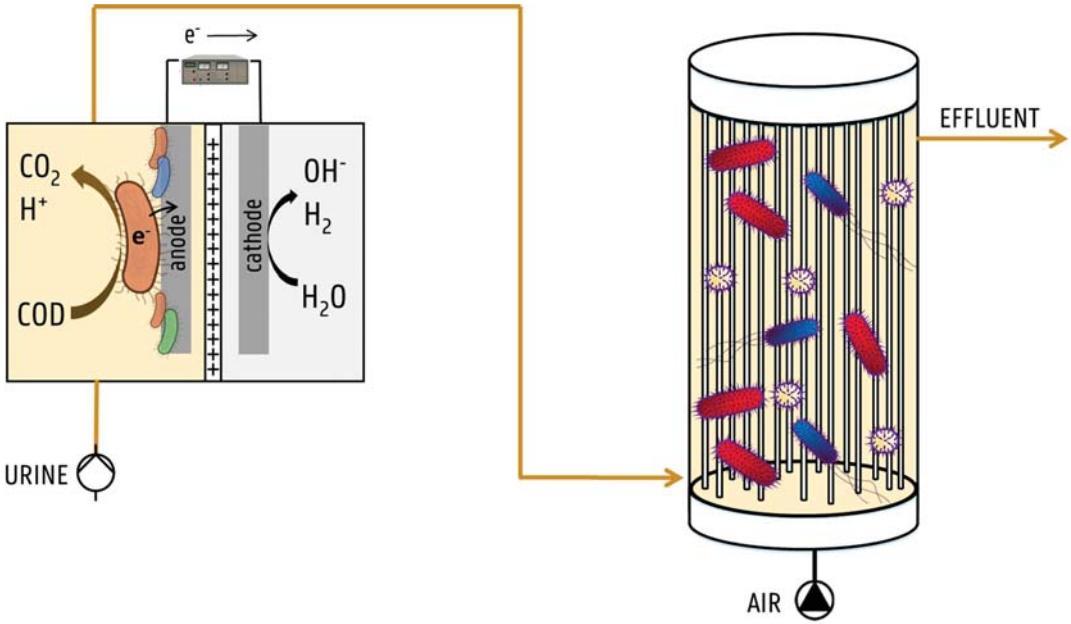
NH_4-N effluent

NO_2-N effluent

COD BALANCE


300
250
200
150
100
50
0
concentration [mg COD/L]
0
10
20
30
40
50
60
70
80
time [d]
influent
effluent

SUCCESSFUL PROOF-OF-CONCEPT



✓> 85% COD removal + complete urea hydrolysis

→ No electron donor for denitrification in MABR

→ No oxygen demand for COD oxidation (~20% reduction)

→ Less sludge production in MABR

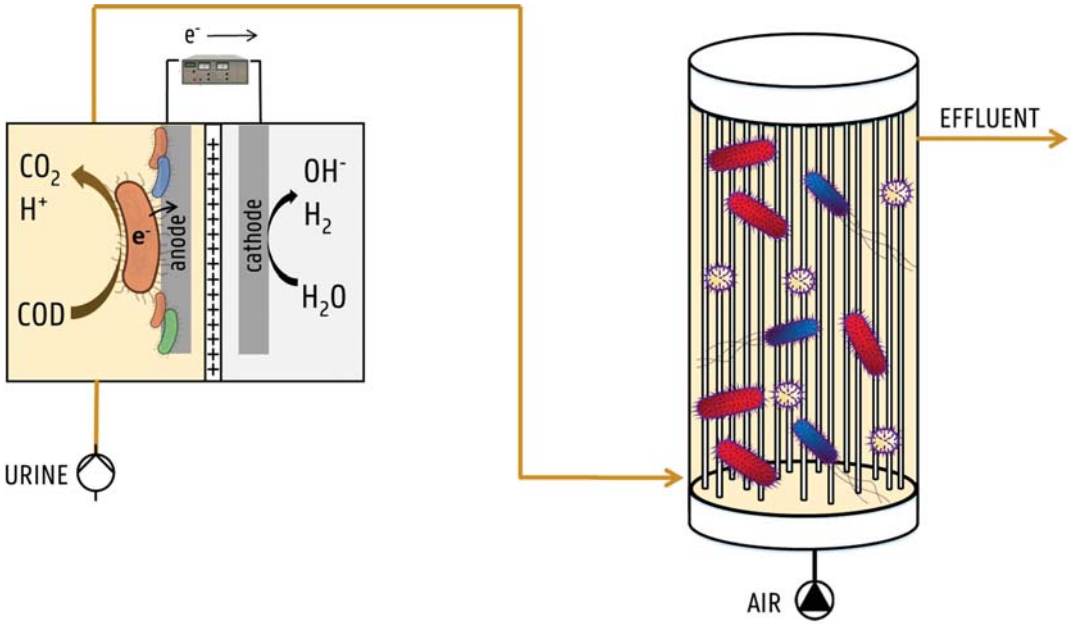
→ Energy production

✓Full nitrification

✓No denitrification

✓High loading → compact reactor

ONGOING WORK



- Improved design and configuration
- Maximum loading
- COD characterization
- Microbial community composition

- Maximum loading
- Microbial community composition

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Funding:
POMP I

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Acknowledgments:

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Robin Declerck
Kim De Paepe
Celine Bauwens
Arne Govaert

EAWAG for providing the urine nitrification culture

Thank you for your attention!