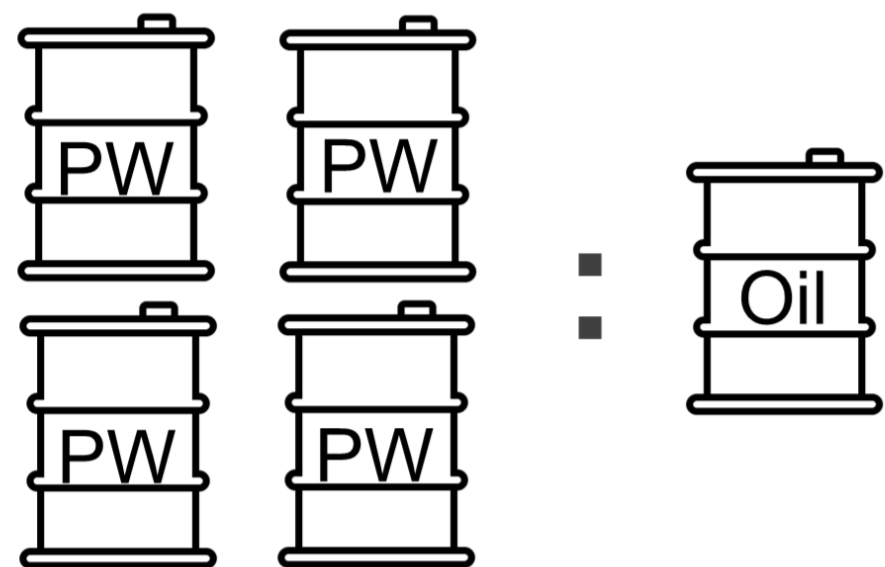


Moving Bed Biofilm Reactor for produced water treatment on the seafloor

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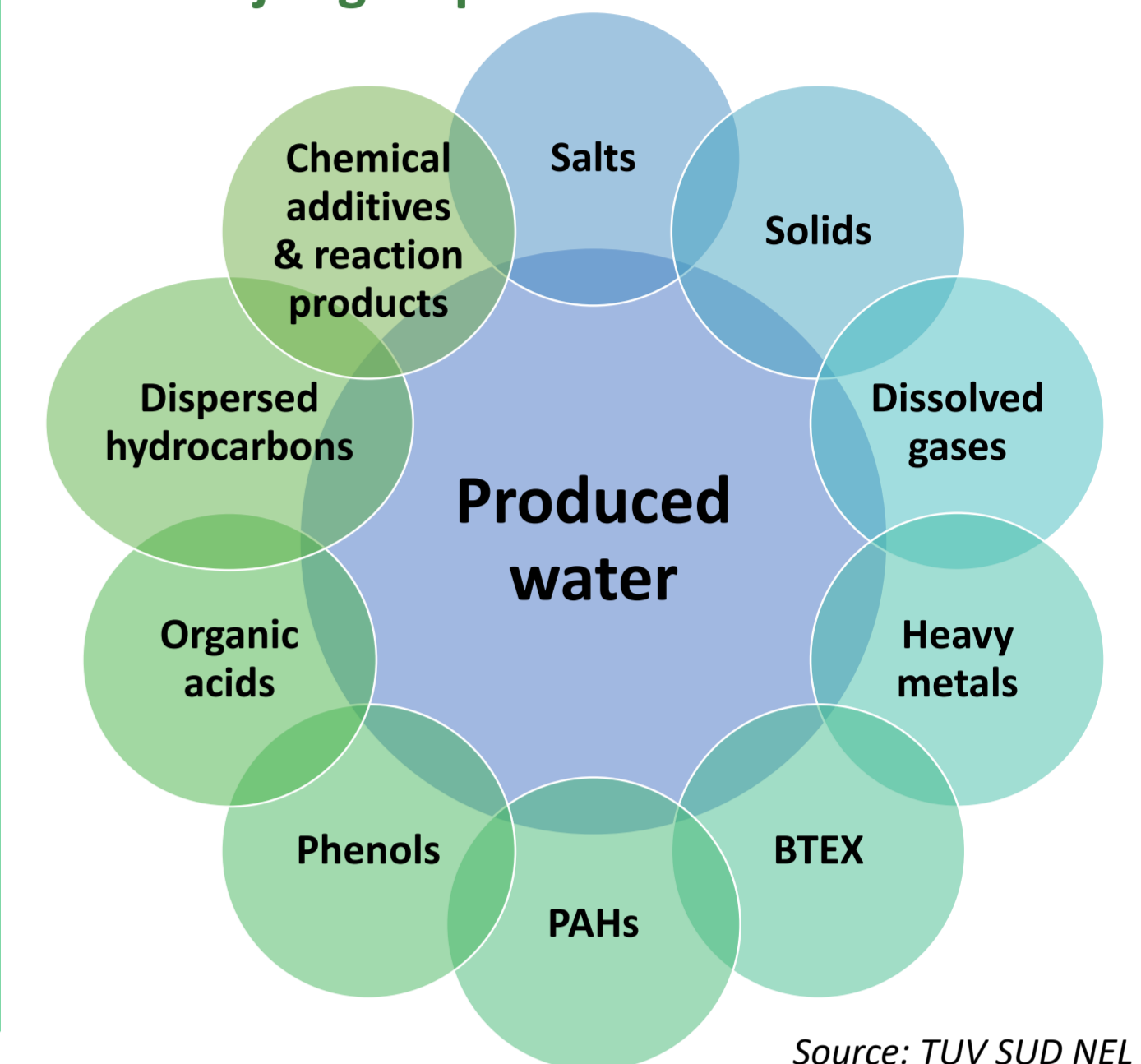
CHALLENGE



The ratio of produced water to oil varies from well to well and over the life of the well.

- Produced water (PW):**
 - largest waste stream generated in oil and gas industry¹;
 - largest direct discharge of effluent into the marine environment worldwide¹;
 - complex composition including high salinity and various toxic compounds²;
 - toxicity assessment studies with aquatic organisms has shown that PW can elicit a range of acute and sublethal effects³;
- Physico-chemical and bioremediation methods that exist are not possible to use at offshore platforms due to:**
 - high footprint and general safety concern also connected with chemicals.

PW major groups of constituents of concern

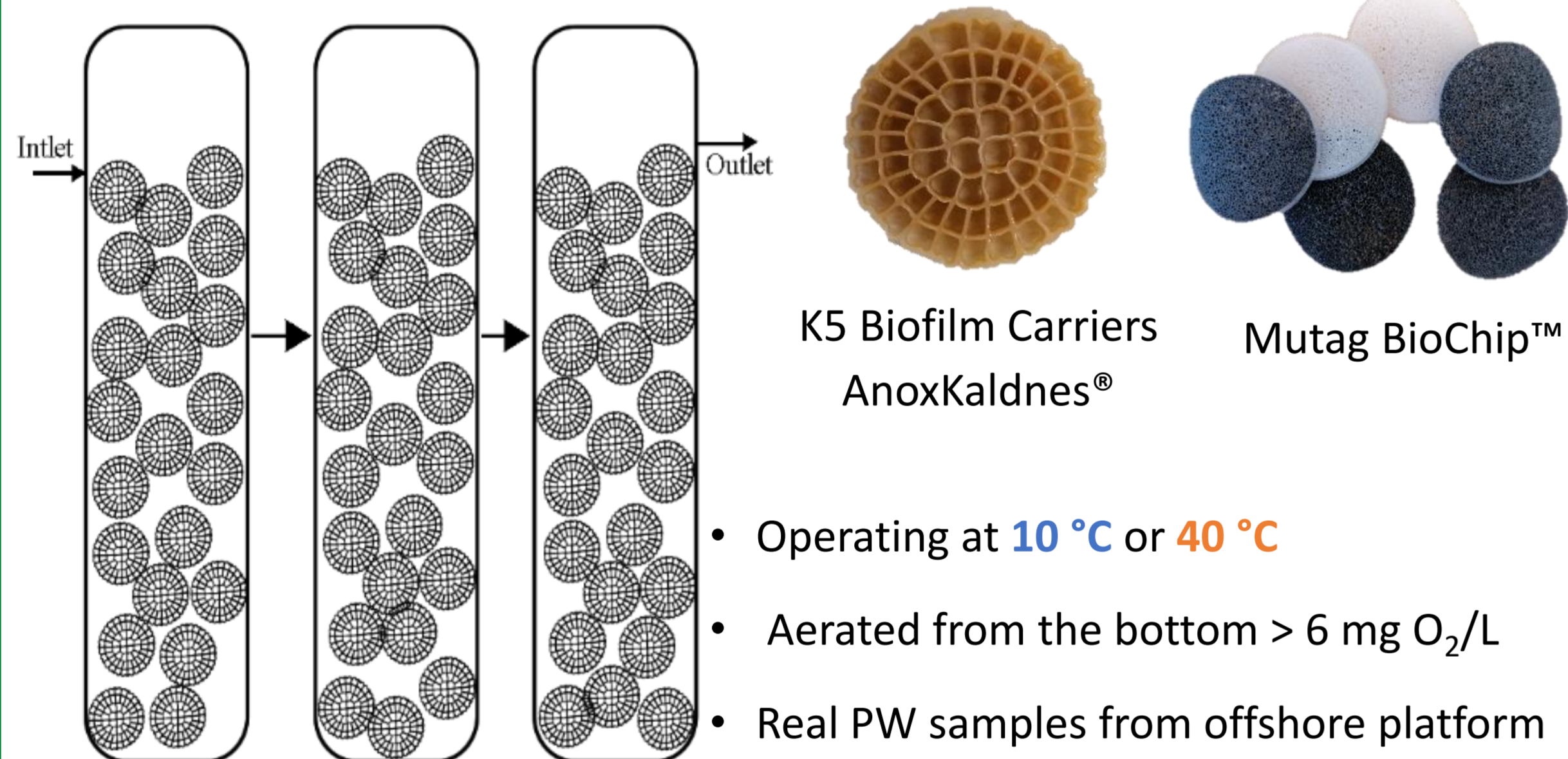


Source: TUV-SUD NEL

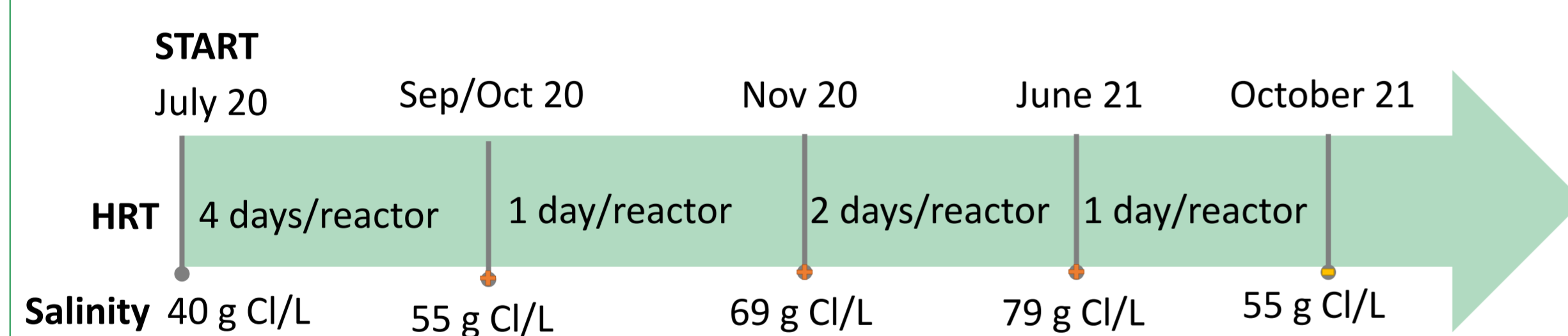
METHODOLOGY

3-stage Moving Bed Biofilm Reactors (MBBR)

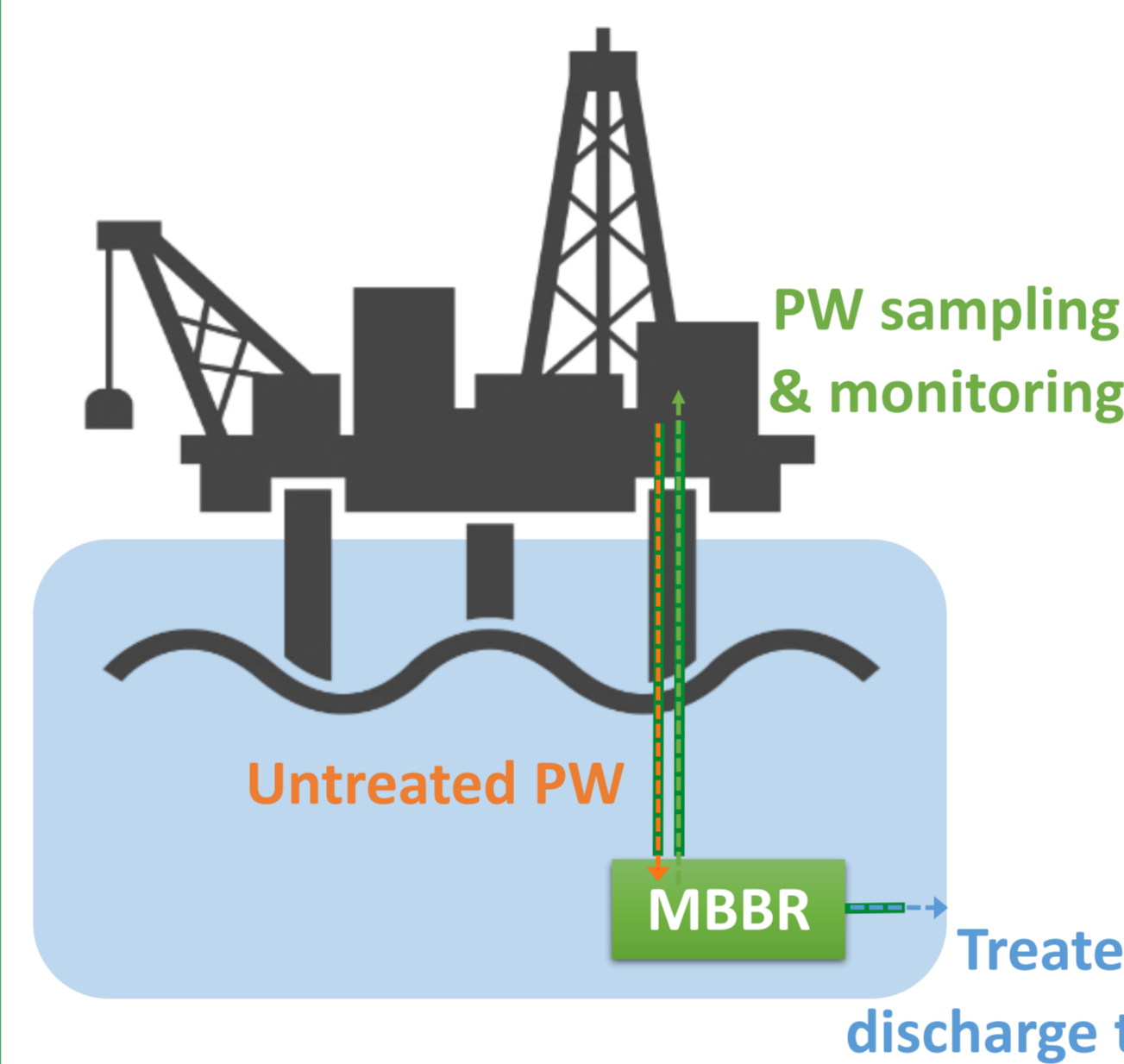
- reactor design and set operational parameters



- changes in reactor operational parameters



SOLUTION



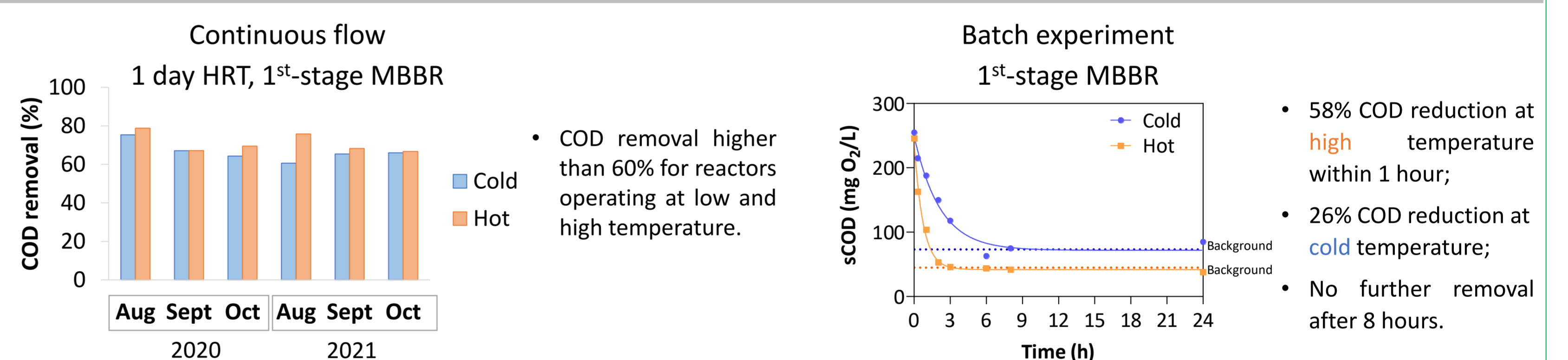
MBBR treatment at offshore platform

- place on seabed taking advantage of high pressure and temperature;
- reduce large fraction of total organic carbon and biodegradation of problematic chemicals

meet future stricter regulation and achieve **zero harmful discharge.**

RESULTS

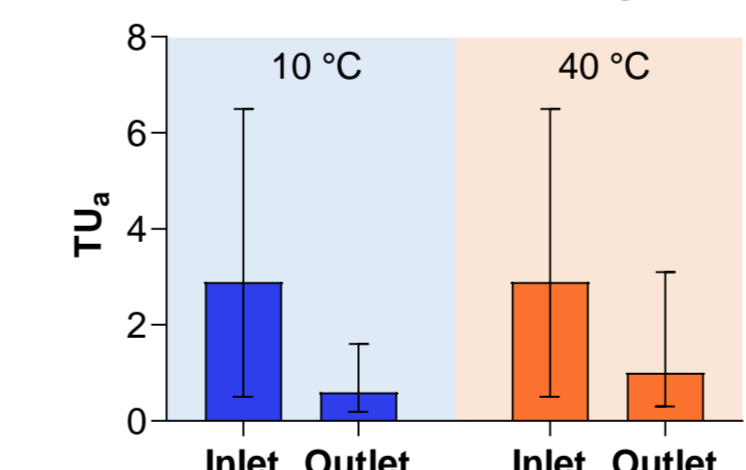
Chemical oxygen demand (COD)



Eco-toxicity

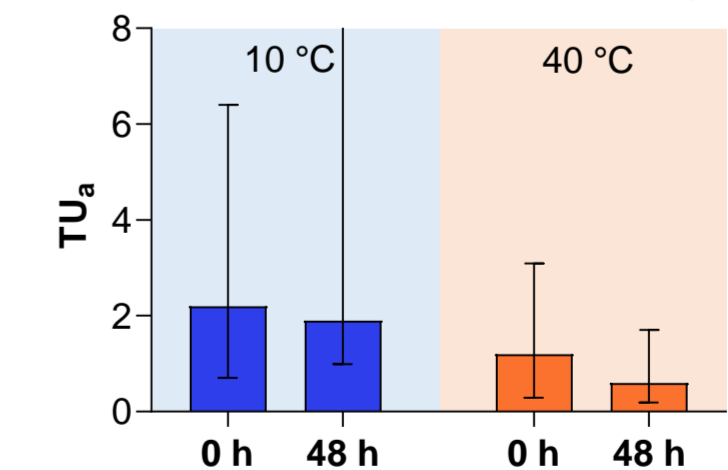
- Tests were carried out with marine algal growth inhibition test with *Skeletonema sp.* (ISO 10256:2016)

Continuous flow 3-stage MBBR



The removal of pollutants concurs with whole water toxicity reduction.

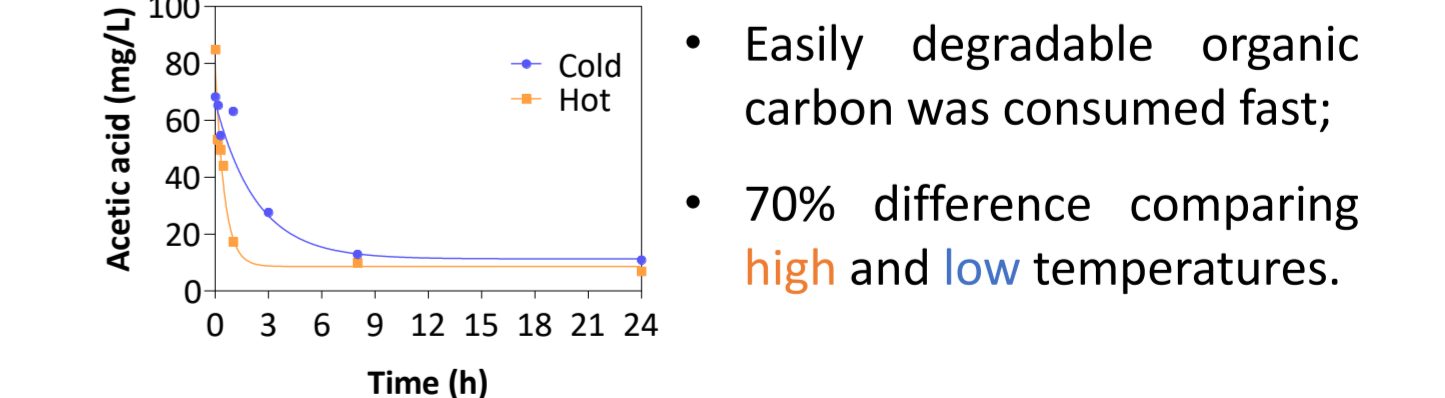
Batch experiment 1st-stage MBBR



Removal of individual compounds

Hydrogen sulphide scavengers	Formula	Untreated PW	Cold	Hot
1,3,4-Trithiolane	C ₂ H ₄ S ₃	33	5	< LQ*
1,2,4,6- or 1,2,4,5 Tetrathiepane (other rings C,H,S)	C ₃ H ₆ S ₄	85	1	< LQ*

Notes: Values in the table include both water and precipitate phase.
* Below the quantification limit



CONCLUSIONS and FUTURE PERSPECTIVES

- MBBR was able to degrade organic molecules such as toxic and persistent chemicals by adapted bacteria that are efficiently retained in the reactors;
- MBBR was able to cope with changes in both PW characteristics and operational parameters made over a year;
- Reactor operated at 40 °C promoted faster removal (~30%) compared to 10 °C in the sea;
- Future research should focus on simulating high pressure reactor and evaluate biofilm performance.

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- Hansen, B. H., Sørensen, L., Størseth, T. R., Nepstad, R., Altin, D., Krause, D., Meier, S., & Nordtug, T. (2019). Embryonic exposure to produced water can cause cardiac toxicity and deformations in Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) larvae. Marine Environmental Research, 148(May), 81–86.

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