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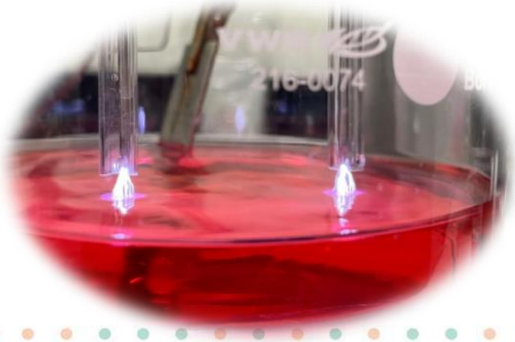
Plasma – liquid interaction for water activation and decontamination

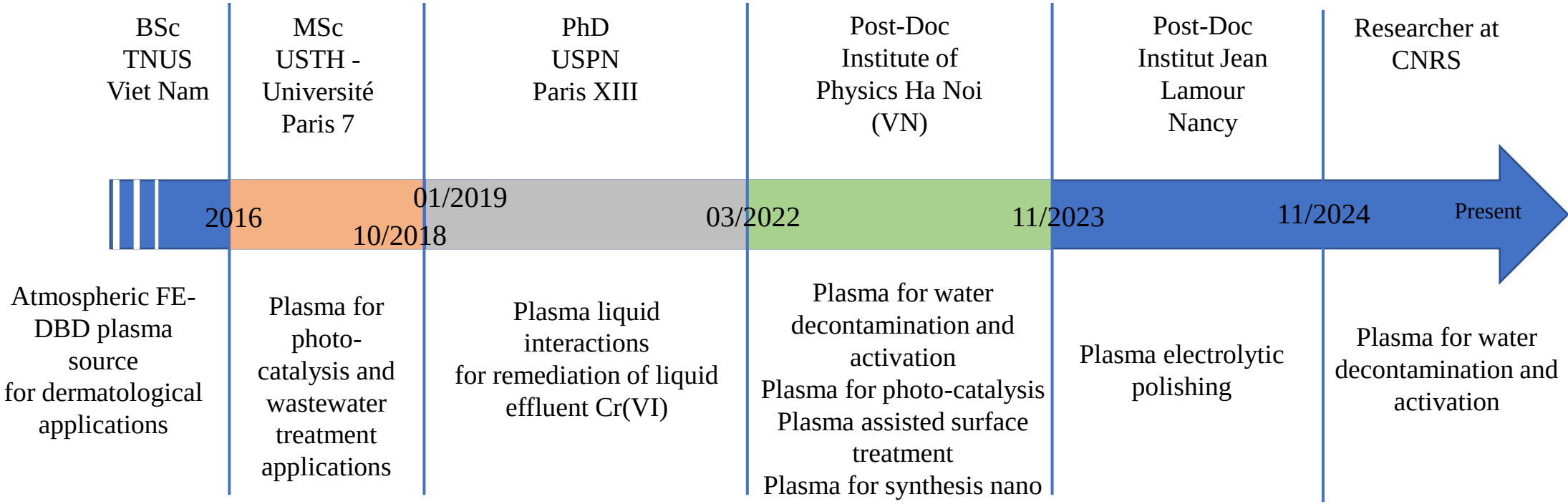
NGUYEN Truong Son*, Thomas GRIES, Cédric NOËL, Thierry BELMONTE, Gerard HENRION, Gregory MARCOS

*Chargé de Recherche CNRS

Institute Jean Lamour - Equipe Plasmas - Procédés - Surfaces - NANCY (France)



My education and background



My primary scientific goal is to understand the physicochemical interactions between plasma and liquid media, and to explore their potential applications.

The Clean Water and Food Crisis

- Water shortages and pollution make it difficult to find clean water for drinking and farming.
- Dirty water harms soil, crops and livestock, leading to poor quality and scarce food.
- Population growth and industrial development exacerbate these problems.

In April 2024:

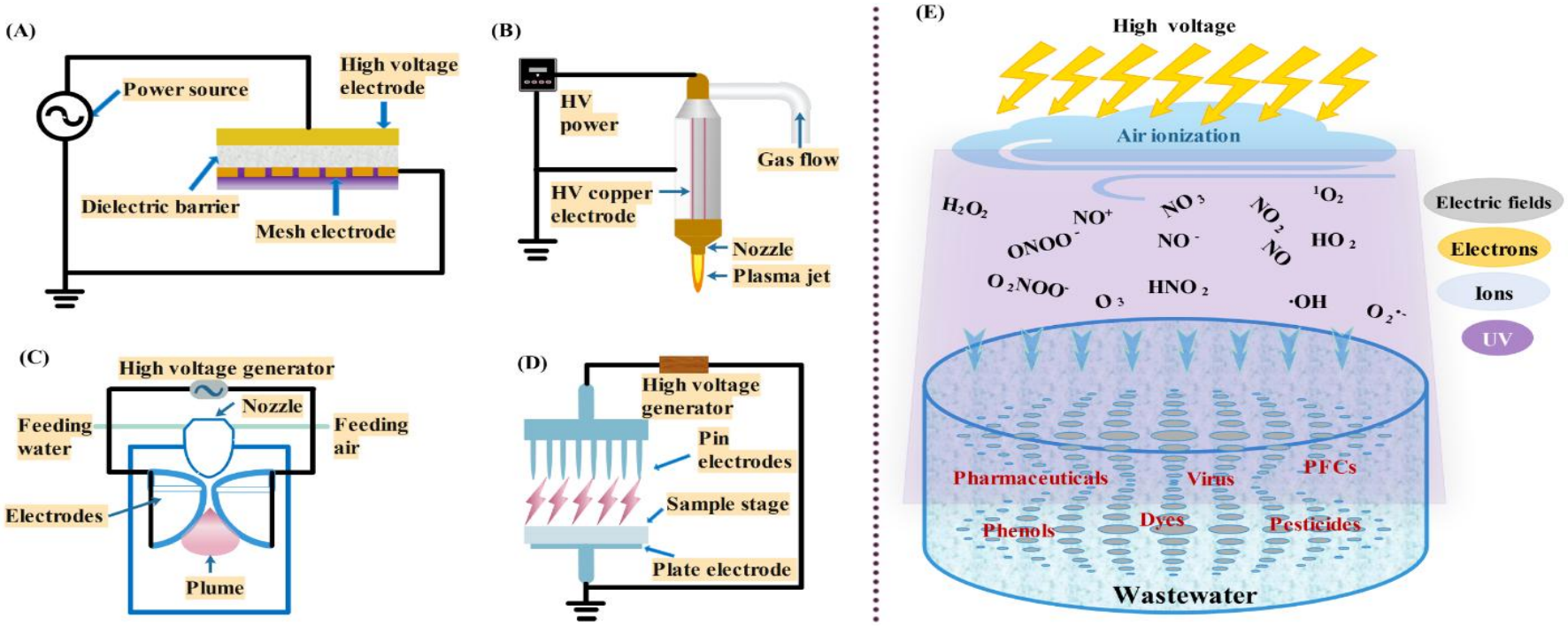
- reports indicated trifluoroacetic acid (TFA) concentrations reached 2900 ng/L in the Seine River [1].
- Cristina Bach and colleagues showed the highest levels of 1,4-dioxane contamination in France, with 4800 ng/L in raw groundwater and 3160 ng/L remaining after treatment [2].

In 2025, drinking water in Nancy contained **830 ng/L of trifluoroacetic acid (TFA)**, mainly from pesticide degradation (e.g., flufenacet, diflufenican) [3]

To ensure the sustainability of clean water, it is important to develop a suitable water treatment technology.

[1] https://www.lemonde.fr/en/environment/article/2024/05/27/the-seine-and-other-european-rivers-contaminated-by-a-forever-chemical-that-has-gone-under-the-radar_6672781_114.html
[2] Bach C et al,.. Arch Environ Contam Toxicol. 2024 Aug;87(2):95-104.
[3] https://www.estrepublicain.fr/environnement/2025/01/23/polluants-eternels-dans-l-eau-potable-l-impuissance-des-elus-locaux

Cold plasma: an environmentally friendly approach with strong application potential



Schematic of several non thermal atmospheric pressure plasma liquid configurations: (A) DBD; (B) plasma jet; (C) gliding arc; (D) corona. (E) Schematic of wastewater plasma treatment [4]

[4] Yin, Y.; et al. Appl. Sci. 2023, 13, 12631. https://doi.org/10.3390/app132312631

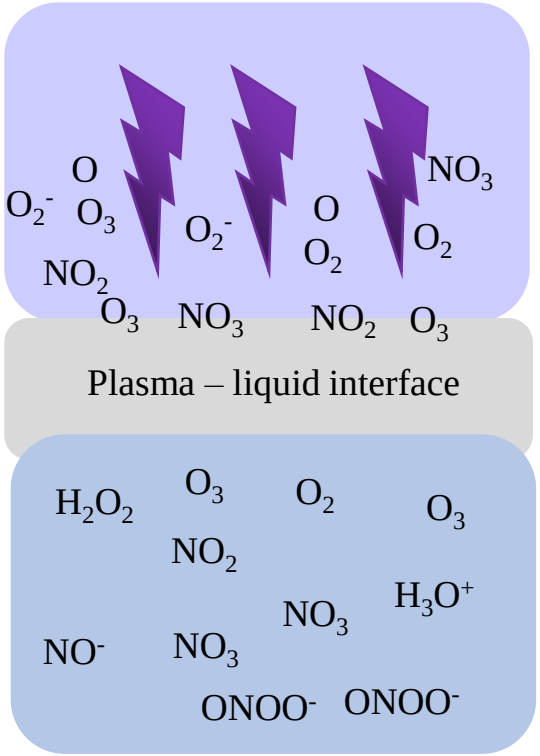
Plasma – liquid interaction for water activation and decontamination

Plasma for / Properties	Water treatment	Water activation
Type of plasma	DBD plasma	Corona plasma
Advantages	• Simple construction • Operation at room temperature • No chemical additives required • High efficiency in generating reactive species • Easy to scaled up	
	Highly reactive species like ozone (O_3) and hydroxyl radicals (OH)	Produce reactive oxygen-nitrogen species (RONS) NO_2^-, NO_3^-, H_2O^-, H, OH, H_2O_2 or HO_2

However, the interaction processes of plasma and liquids are complex and still not fully understood.

Objectives - academic research

Address these issues of complexity and poor understanding of the plasma-liquid interaction



Objectives - academic research

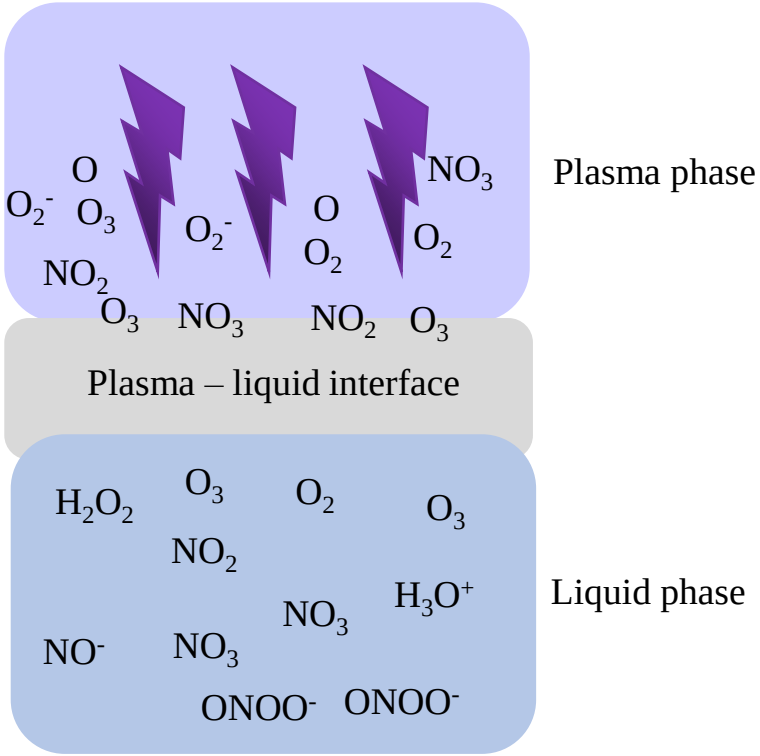
Address these issues of complexity and poor understanding of the plasma-liquid interaction

Plasma physico-chemical processes

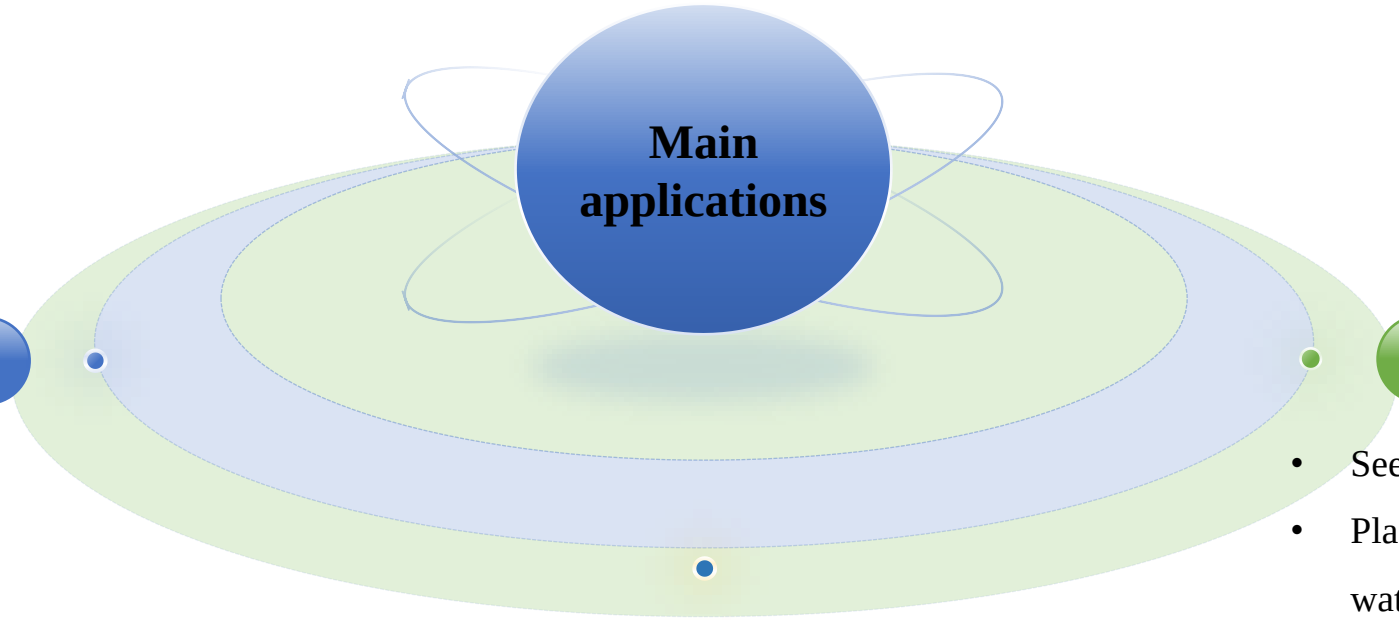
Transfer of species from plasma to liquid phase

How their species interaction with liquids and the components in liquid phase

Better understanding of the modification of the solution by plasma species



Objectives - applications



For health

- Wound healing
- Sterilization
- dermatology

For sustainable agriculture

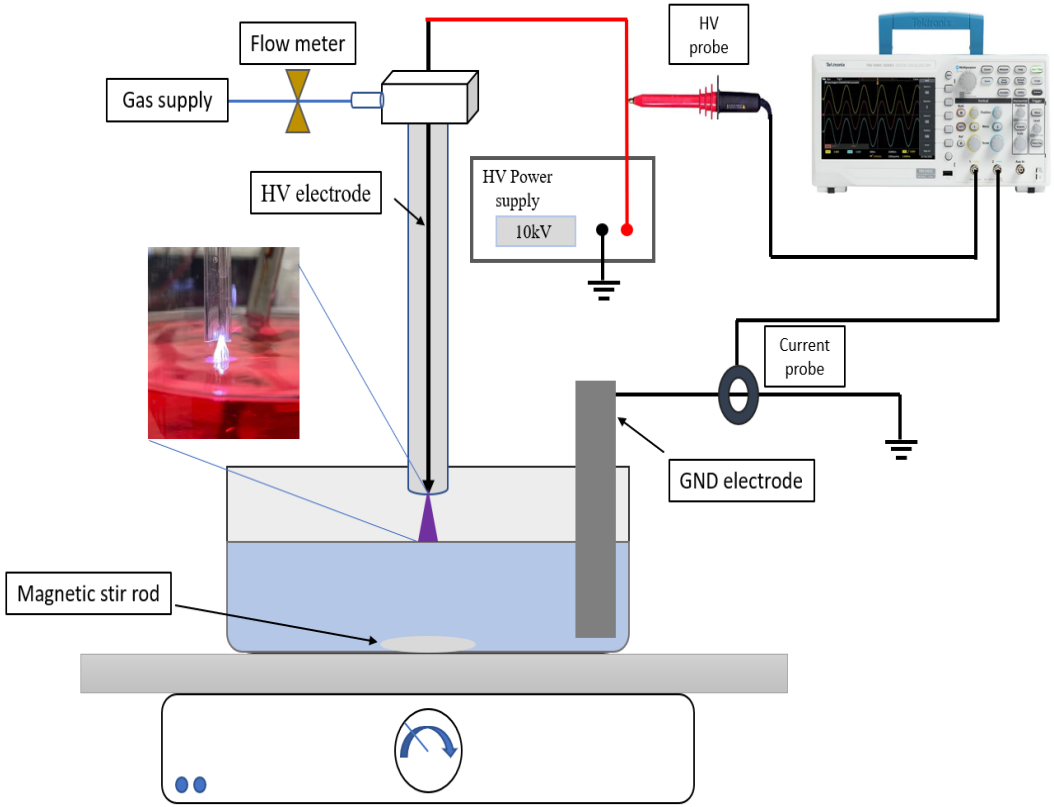
- Seed treatment
- Plasma-activated irrigation water (PAW)
- Post-harvest treatment

For the environment

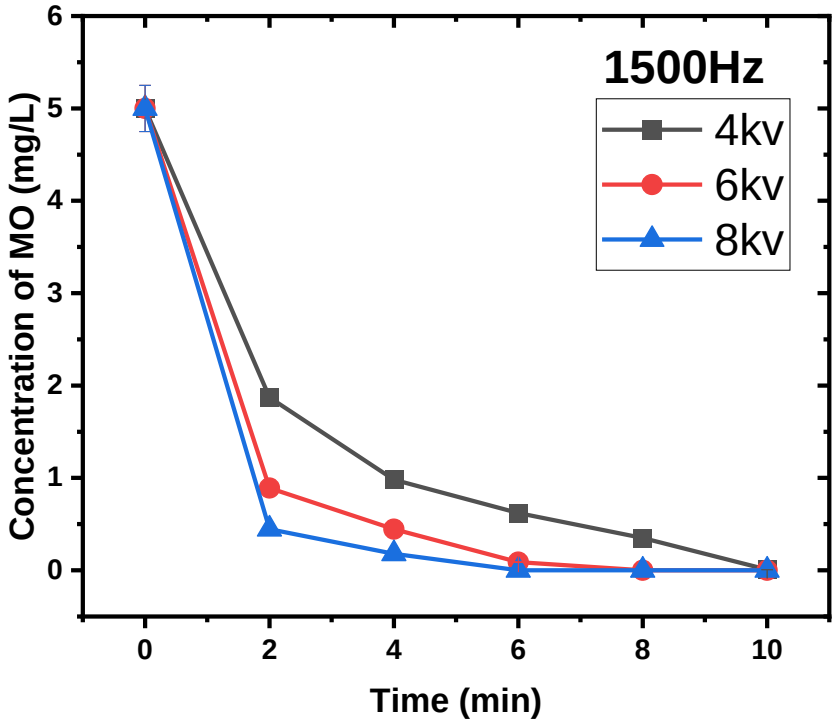
- Waste water treatment
- Air and gas treatment
- Resource recovery and circular use...

Preliminary results – For water treatment

Plasma discharge above liquid



Plasma Decomposition of Methyl Orange

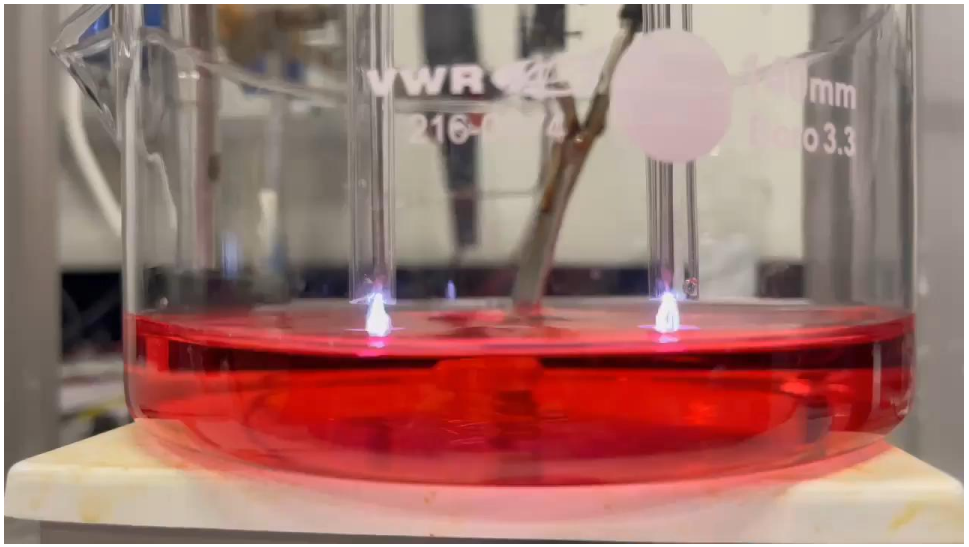


>91% degradation by 2 min at 8kV

even 4 kV achieves >90% degradation by 4 min

Preliminary results – For water treatment

Plasma discharge above liquid

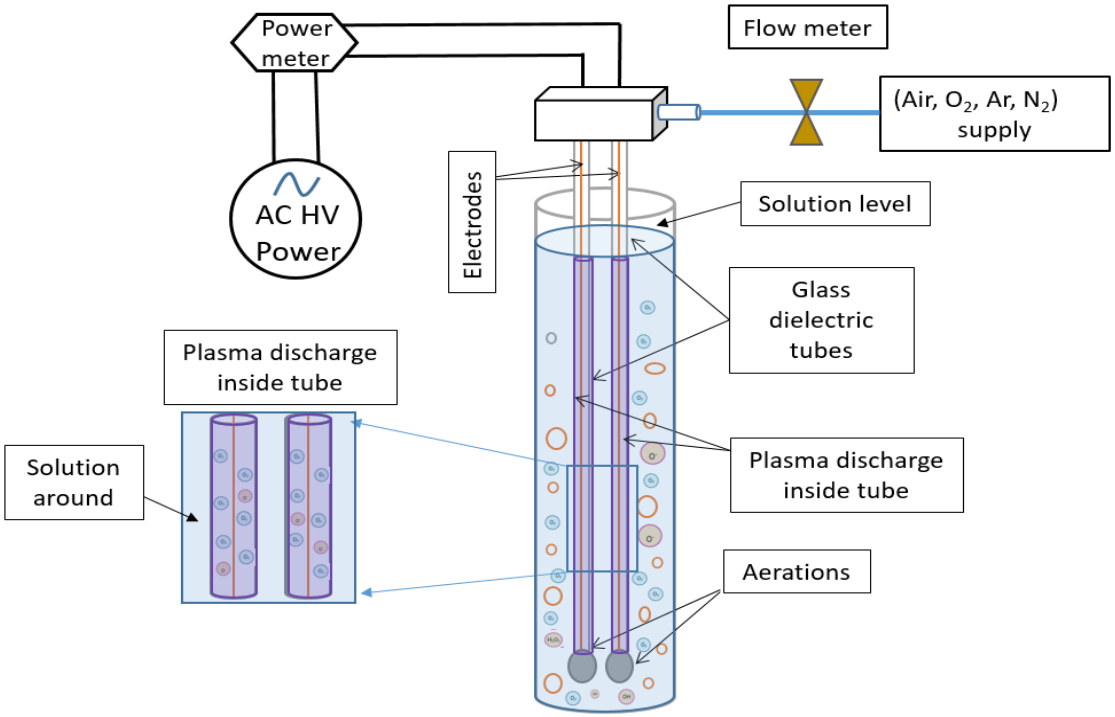


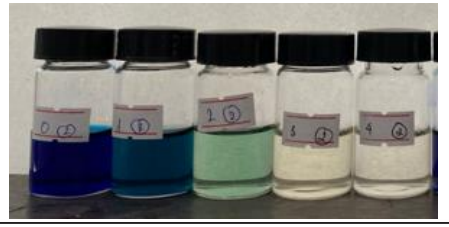
Types of discharge	Conditions	Removal efficiency	Energy yield	Refs
Pulsed electrical discharge	V = 450mL, C =10 mg/L, t = 15mn, pH = 6.6, U = 22-30kV, f = 50Hz, O_2	84.3%	0.45 g/kWh	[5]
Pulsed electrical discharge	V = 25 mL, C = 100mg/mL, U = 16kV, pH = 2.2, Ar	97%	0.6 g/kWh	[6]
Pulsed electrical discharge	V=200mL; C = 100mg/L, t = 30mn, P = 6W, with support of activated cacbon fibers + H_2O_2	90%	0.51 g/kWh	[7]
DBD plasma	V = 25mL, C = 100 mg/L, t = 35min, pH = 6.25, U = 22kV, f = 25Hz, Air	96.8%	0.46 g/kWh	[8]
Pulsed DC plasma discharge	V = 150 mL, C = 5 mg/L, t=10 min, pH = 7.2, U = 8 kV, f=500-1500Hz, Ar	100% 91.1%	0.8g/kWh 1.15g/kWh	This work

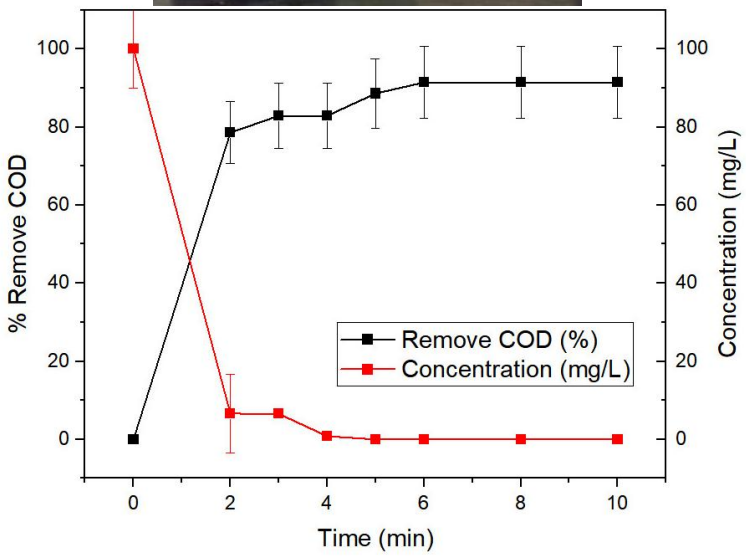
[5] BingSun et al,. Journal of Environmental Sciences, 24(5):840–845, 2012.
[6] Yui Hayashi et al 2014 Jpn. J. Appl. Phys. 53 010212.
[7] BoJiang et al,. Chemical engineering journal, 215:969–978, 2013.
[8] Fangmin Huang et al,. Journal of Electrostatics, 70(1):43–47, 2012

Preliminary results – For water treatment

DBD plasma discharge inside liquid



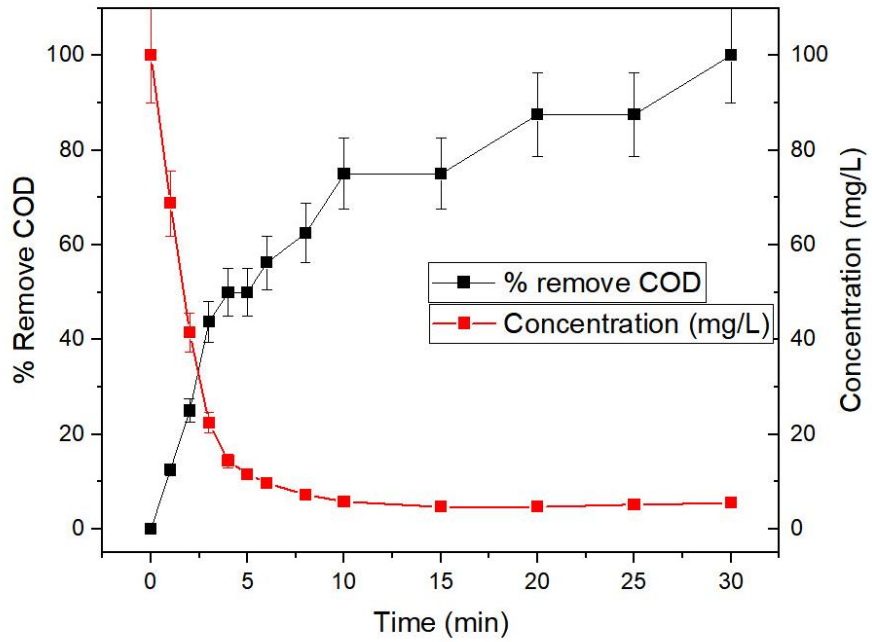




After 2 minutes:

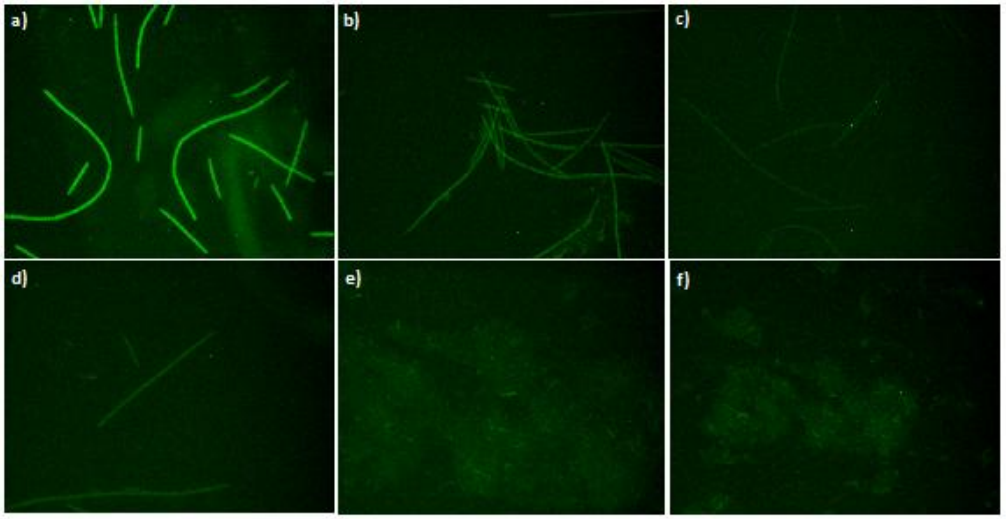
- Concentration was reduced by more than 90%
- COD removal value ~80%

Preliminary results – For water treatment



After the first 3 minutes of processing:

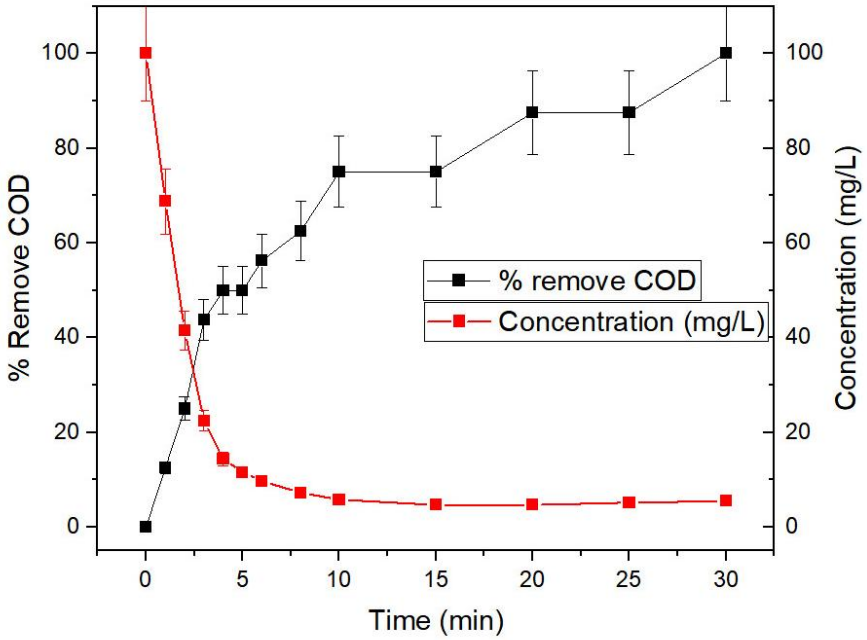
- Paracetamol concentration has decreased ~80% %
- COD removal ~50%
- % COD removal reached ~80% after 10 minutes and 100% after 30 minutes



Dolichospermum cells under fluorescen microscope before and after plasma exposure. a) before plasma exposure; b-f) after 30, 60, 120, 180 and 300 second of plasma exposure [9]

[9] T.Son Nguyen et al. Vietnam Journal of Science and Technology. 2023

Preliminary results – For water treatment



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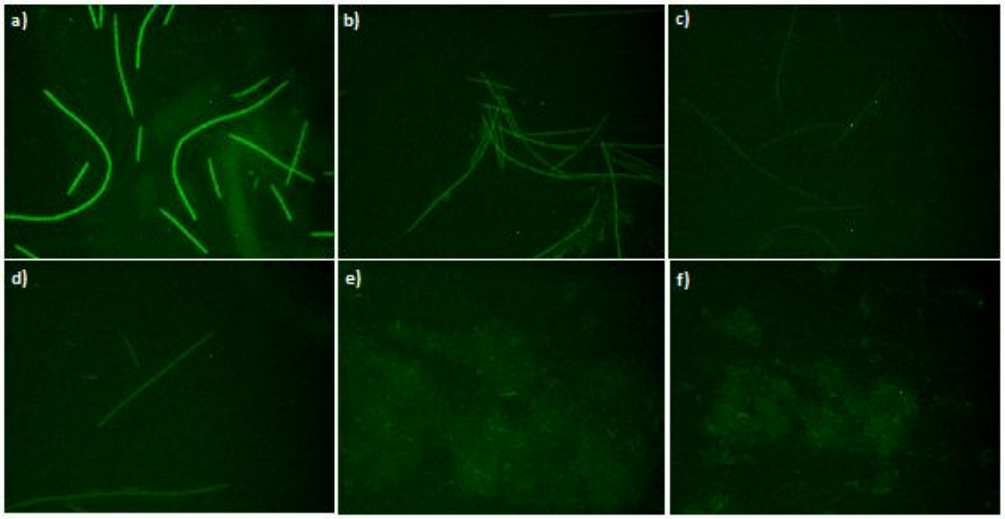

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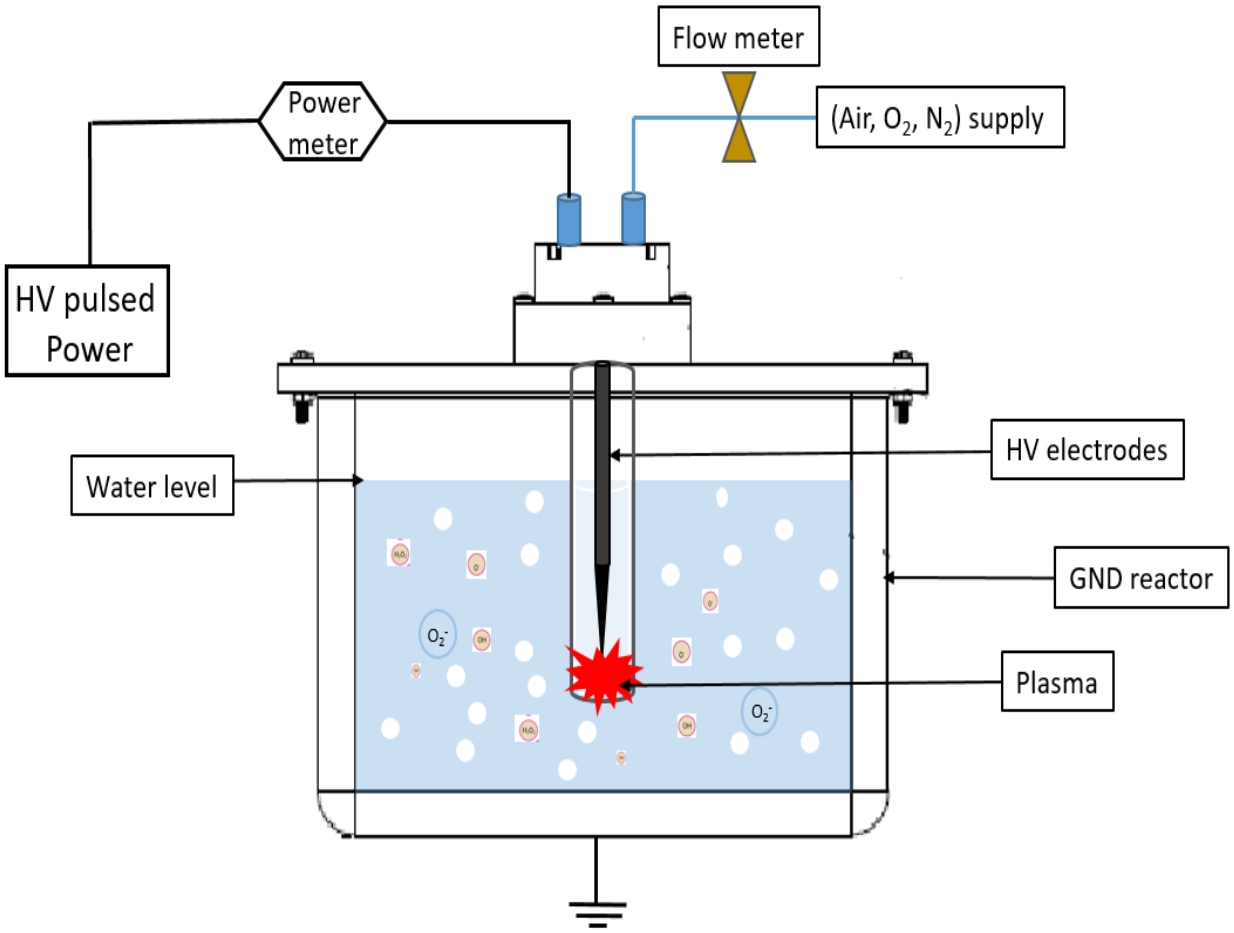
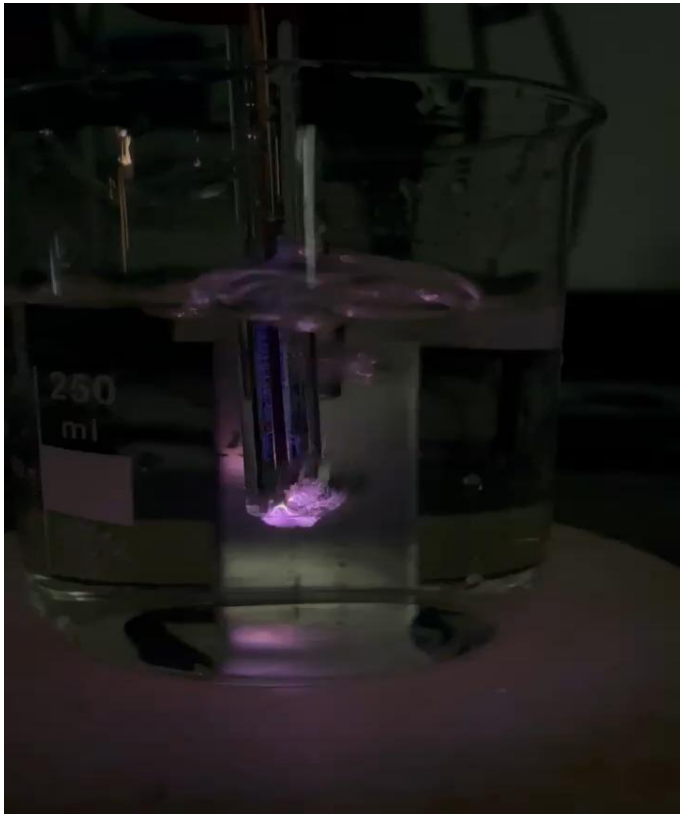
Preliminary results – For water activation

Plasma discharge inside liquid





V = 250ml tap water
U = 8kV
f = 500Hz
t = 5 min
Gas N_2 :2l/min

Incubation of red radish seeds by PAW

Tap water

PAW

After 24h

30% of seeds germinated for tap water

100% of seeds germinated with PAW

After 30h

Seeds using PAW produce cotyledons

After 3 days

Seeds produce plants (some plants over 5 cm tall)

How?????????

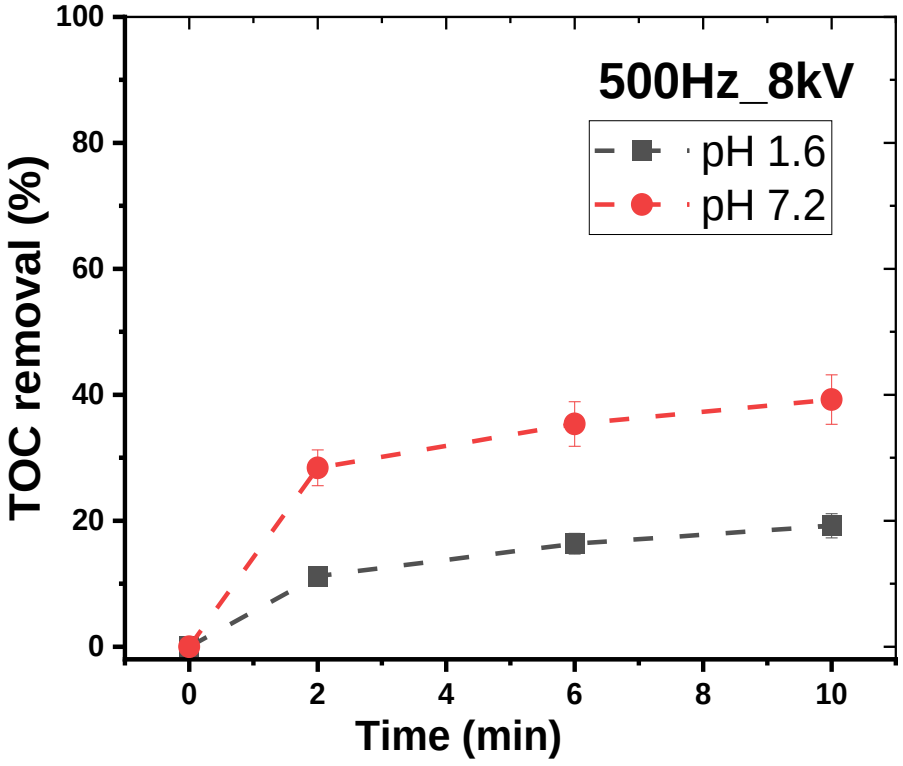
1. • Mechanisms – What are the key biological and chemical mechanisms that explain the effects of plasma?
2. • Scalability – How can lab-scale plasma systems be scaled up to farms, hospitals, and industry at practical size and cost?
3. • Integration – How can plasma be integrated into existing agricultural and medical practices without disrupting them?
4. • Safety – How safe is plasma (or PAW) for long-term use on water, plants, soil, humans, and medical treatments?

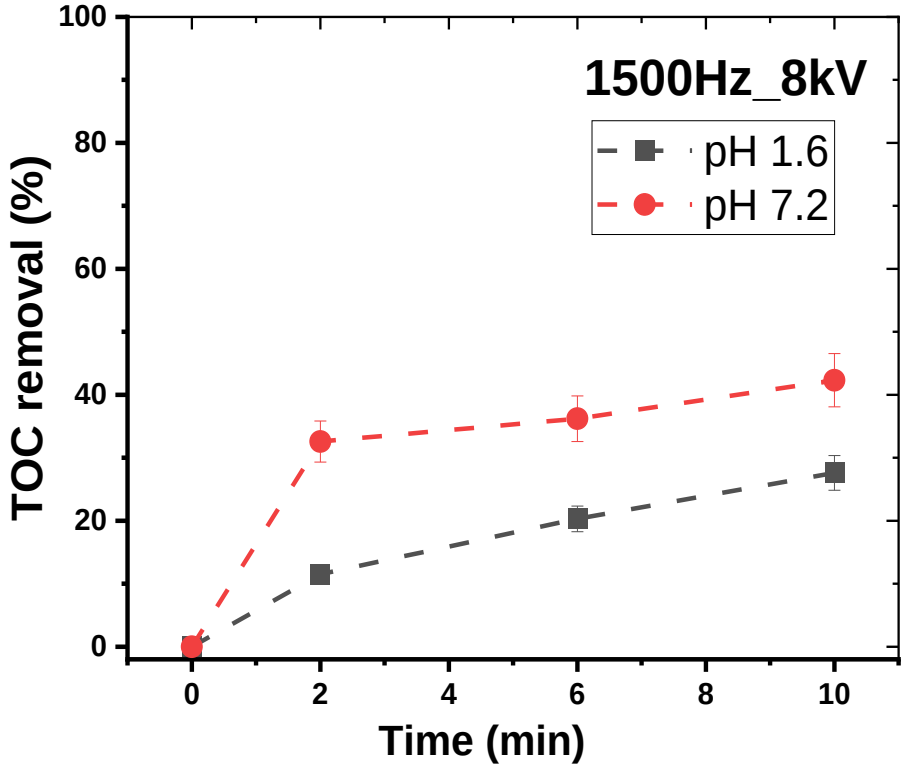
My goal is to find answers to these key questions.

Thank you
for listening

TOC measurement

[MO] = 5mg/L, Initial conductivity: **42 mS/cm,** f = 500 and 1500 Hz, voltage: 8 kV, time = 2, 6, and 10 minutes

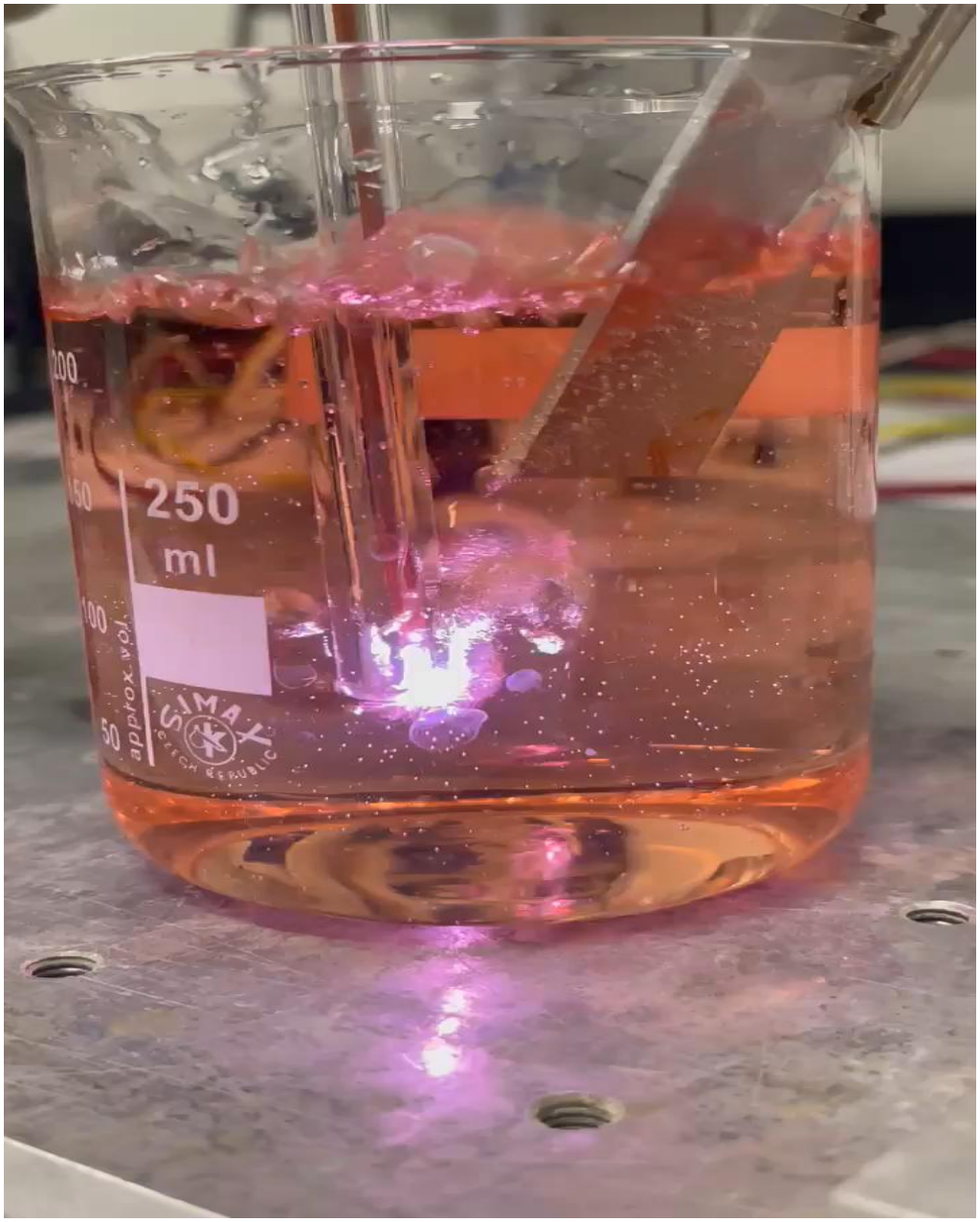




- The removal of TOC increases with time and frequency.
- Faster during first 2 min: up to ~ 30-33% and then slowly increased
- ↗ frequency => ↗ % TOC removal (but not a huge significant)

=> Not total mineralization

Improvement plan to increase efficiency



ciprofloxacin (CIP) and sulfamethoxazole (SMX)