Innovative plasma technologies for the treatment and reuse of water

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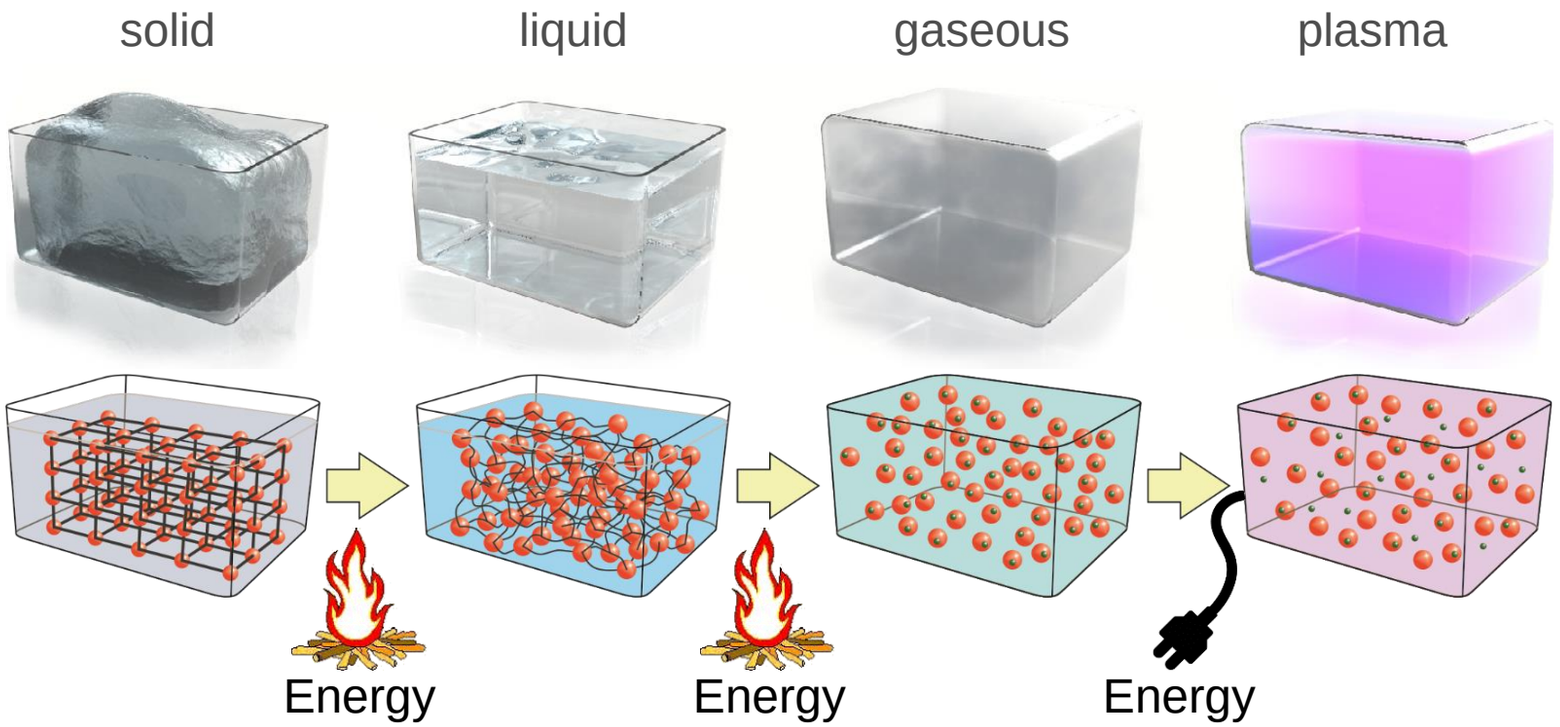
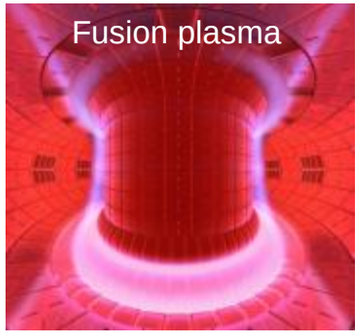
Leibniz Gemeinschaft

FROM IDEA TO PROTOTYPE

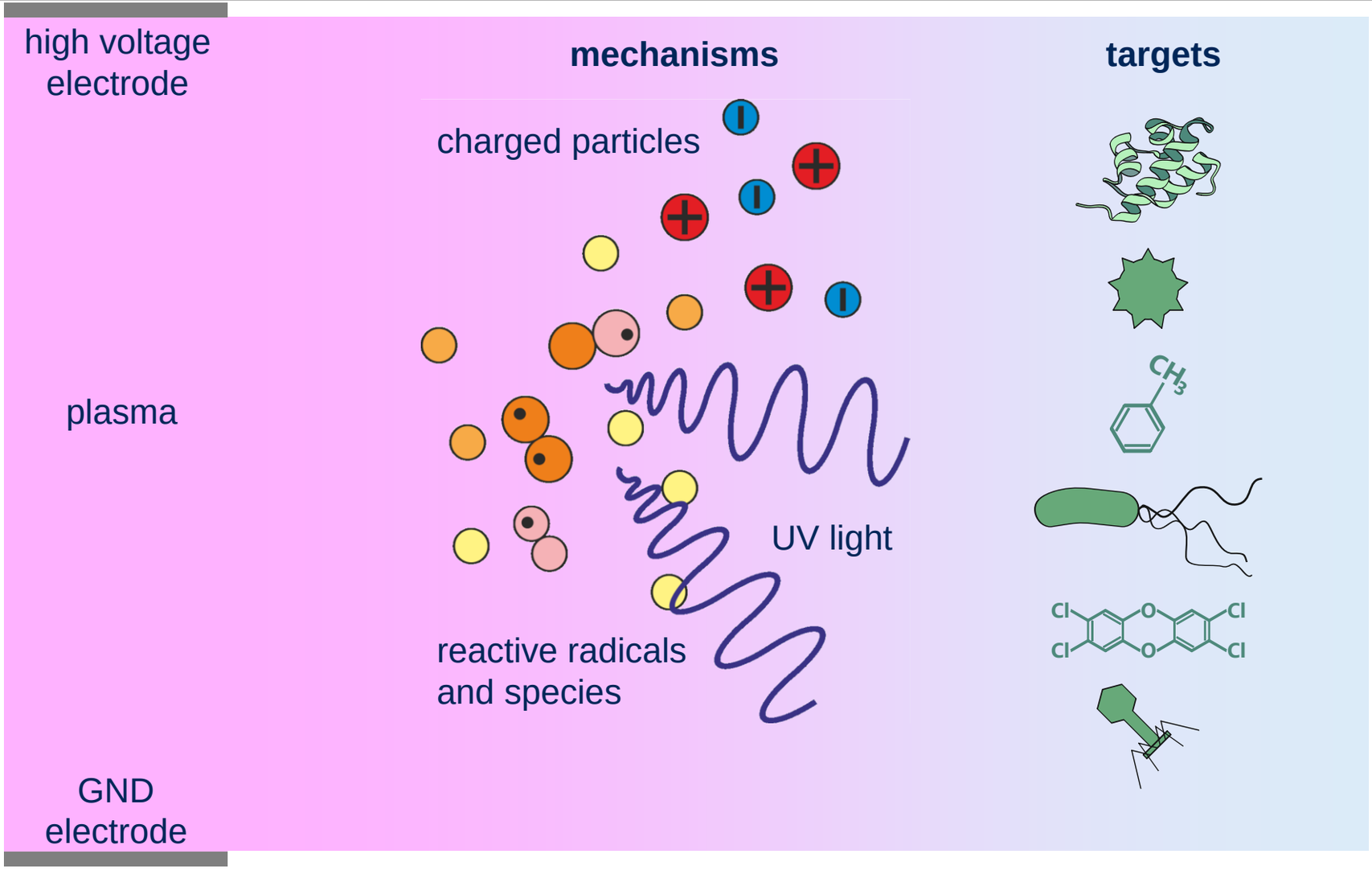
What is plasma?





The benefit of technically exploited plasmas is usually hidden in the final product.

Water treatment by plasma – “Mode of action”



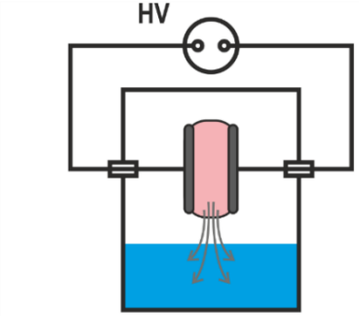
Low-temperature plasmas induce various physical and chemical processes that can effectively be used for the inactivation of microorganisms and the degradation of organic compounds.

Unique advantages of water treatment by plasma

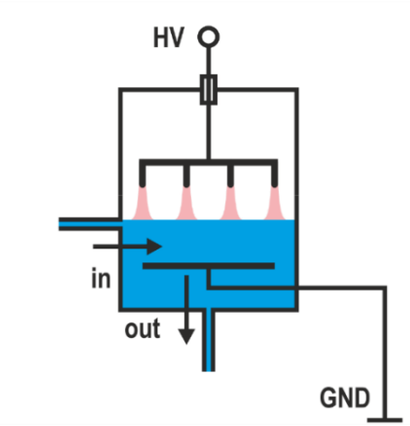
- No chemicals, catalysts or other additives necessary
- Inactivation of microorganisms, including multidrug-resistant bacteria
  - No microbial resistances against plasma treatment
- Decomposition of persistent and recalcitrant organic compounds
  - Even those that are not or less susceptible to other advanced treatments
- Tailor-made systems adapted to specific situations and requirements
  - Plasma can be generated in gas, in water or at the interface
  - Type and dose of produced reactive species can be controlled
- Easy handling and ‘on demand‘-operation

Plasma configurations for the treatment of water

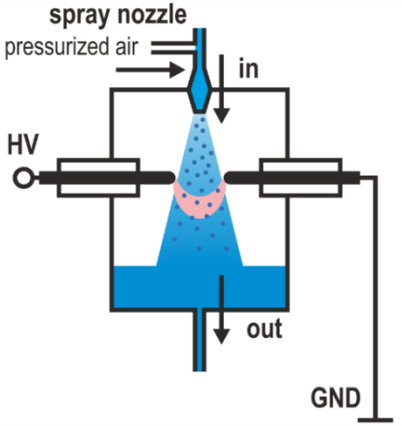
Introduction of plasma effluents (e.g. ozone)



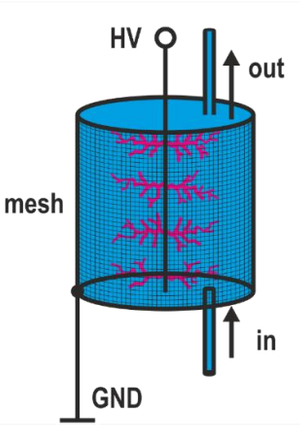
Pin-to-water surface spark discharge



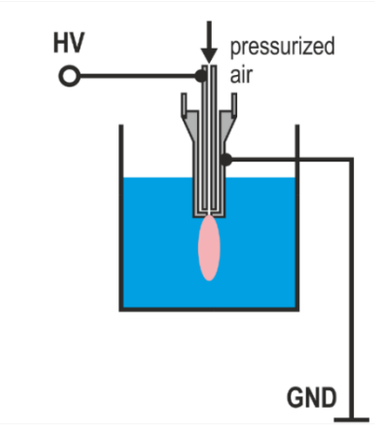
Water spray through arc discharge



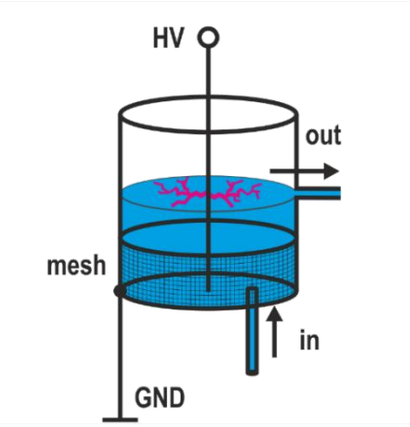
Submerged pulsed corona-like discharge



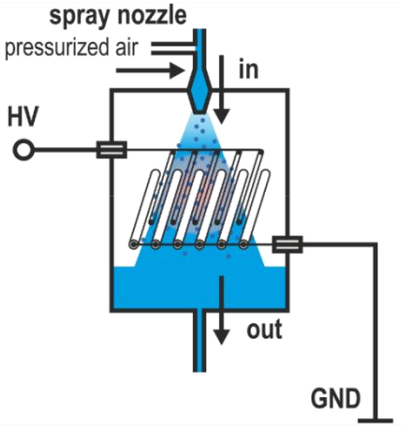
Submerged plasma jet



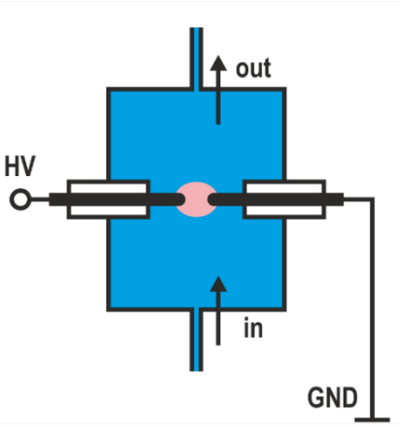
Pulsed corona-like discharge along water surface



Water spray through pulsed dielectric barrier discharge



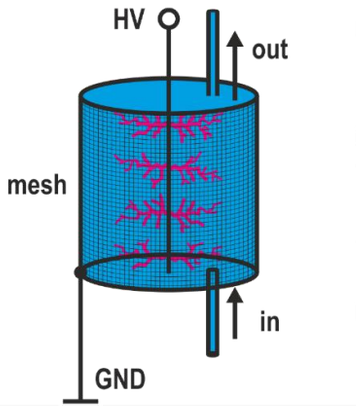
Submerged spark discharge

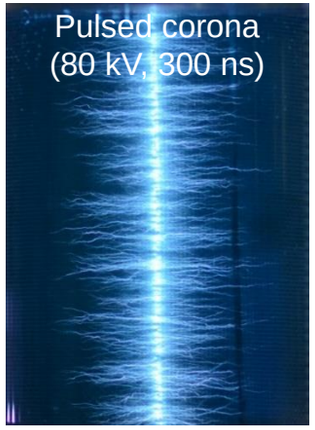


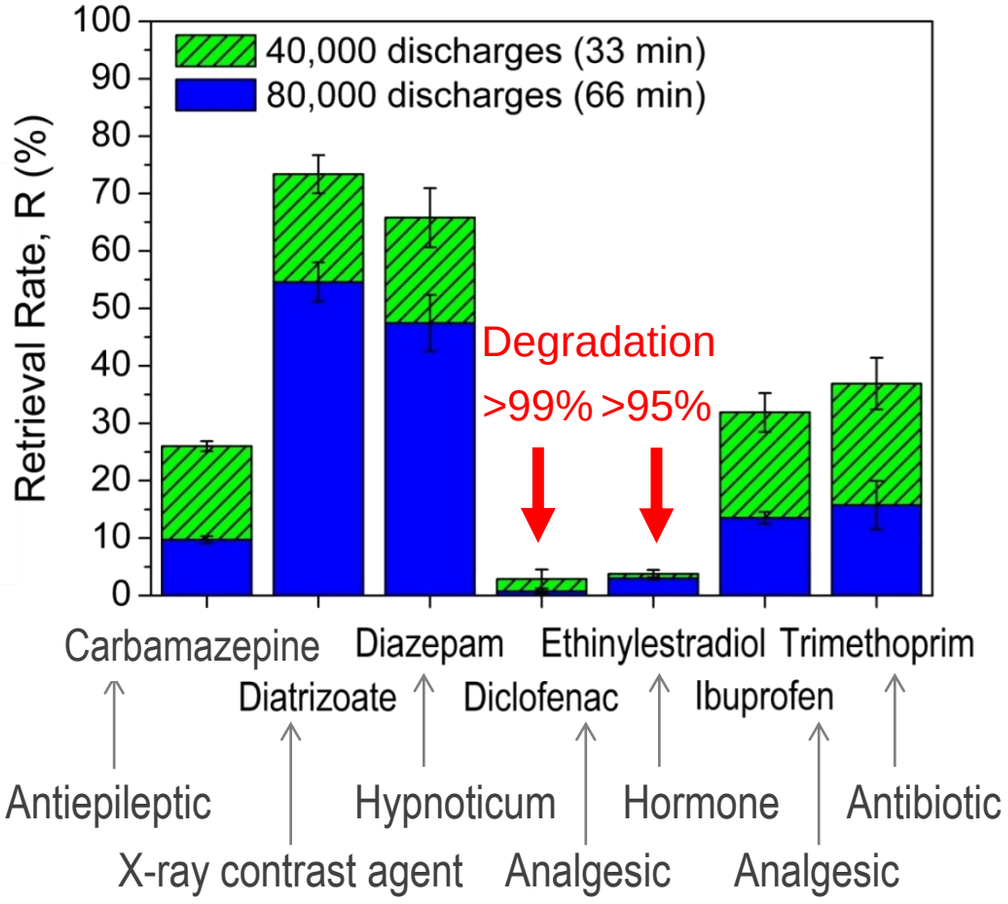
M. Schneider, R. Rataj, L. Blàha, J.F. Kolb, "Experimental review of different plasma technologies for the degradation of cylindrospermopsin as model water pollutant," Chem. Eng. J. 451 (2023) 138984.

Water treatment by plasma – Examples from the laboratory (1)

Submerged pulsed corona-like discharge



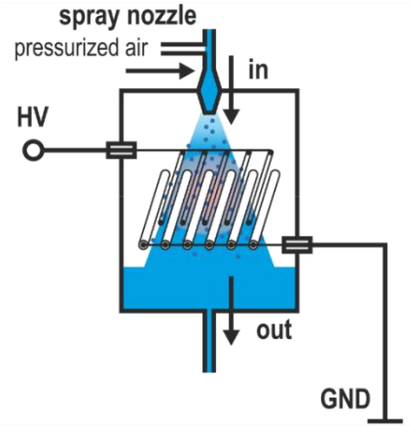


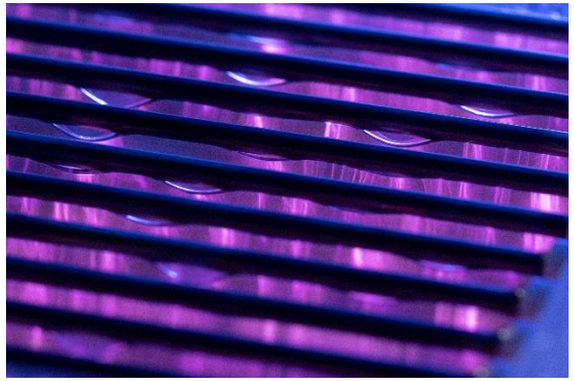


Pharmaceutical	EEO (kWh/m^3)
Diclofenac	27
Ethinylestradiol	32
Carbamazepine	80
Ibuprofen	97
Trimethoprim	114
Diazepam	258
Diatrizoate	430

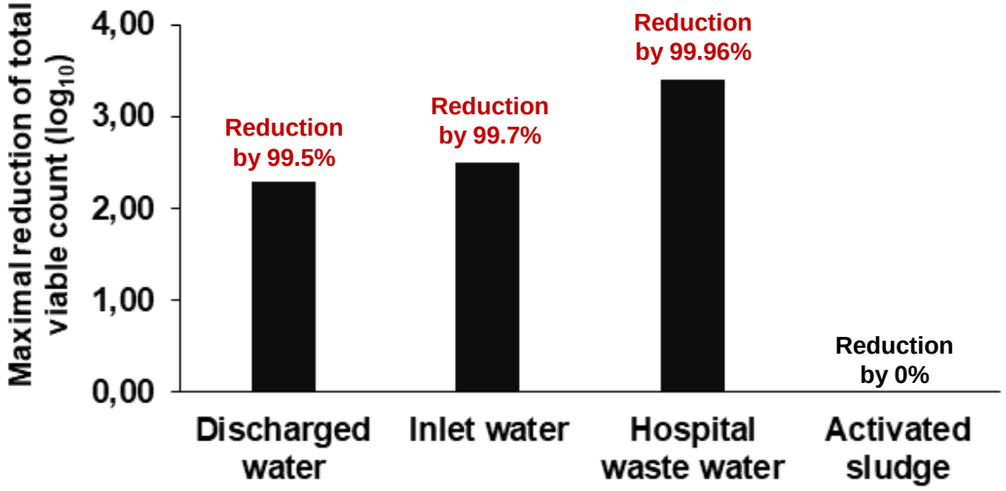
R. Banaschik, P. Lukes, H. Jablonowski, M.U. Hammer, K.-D. Weltmann, J. Kolb, "Potential of pulsed corona discharges generated in water for the degradation of persistent pharmaceutical residues," Water Research 84 (2015) 127-135.

Water spray through pulsed dielectric barrier discharge





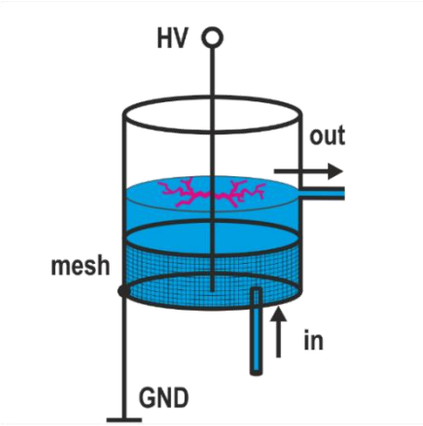
Antibiotic-resistant bacteria

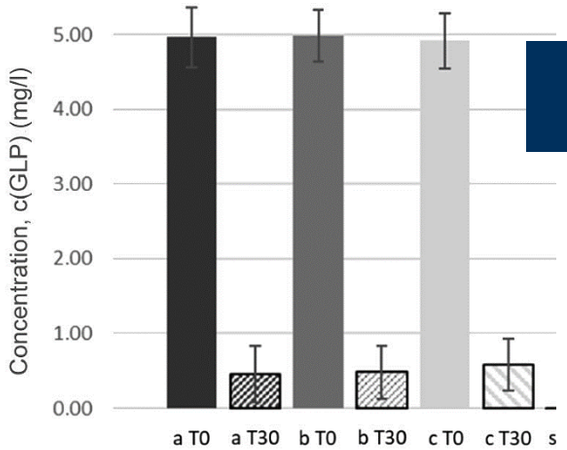


AntiRes 2.0 (in cooperation with University of Greifswald)

Water treatment by plasma – Examples from the laboratory (2)

Pulsed corona-like discharge along water surface



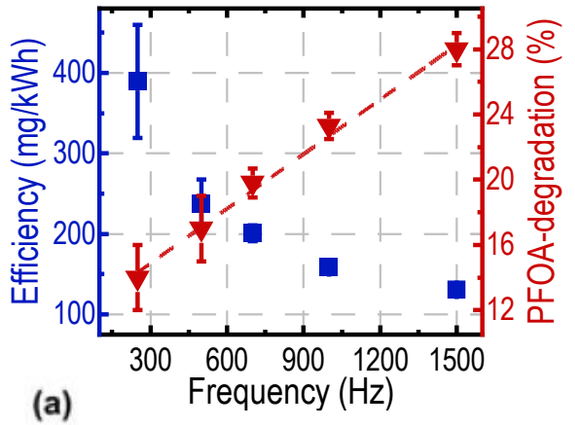


~ 91 % Glyphosate degradation after 30 min (-> 0,32 g/kWh)

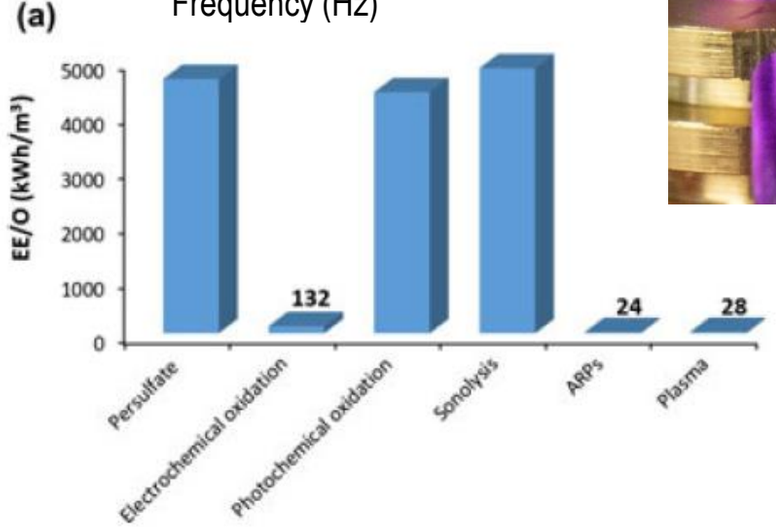
Degradation of Glyphosate after 30 min of plasma treatment (T0 = before treatment, T30 = after 30 min of treatment, n = 3).

K. Zocher, P. Gros, M. Werneburg, V. Brüser, J.F. Kolb, P. Leinweber, "Glyphosate degradation in water by applying surface-corona-discharges," Water Sci. Technol. 84 (2021) 1293

PFAS also known as ***forever chemicals***



Water spray through pulsed dielectric barrier discharge

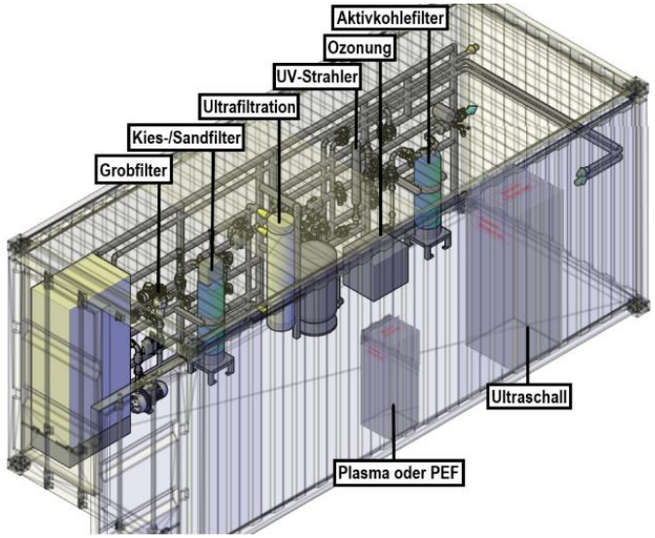


Electrical energy per order (EE/O), i.e. the electrical energy that is required to reduce PFOA by 90 % in 1 m³ of water, for various advanced water treatment methods.

M. Buckstöver *et al.*, "Process parameters and constraints for the degradation of perfluoroalkyl substances in water by a volume dielectric barrier discharge," submitted to *Chemical Engineering Journal*.
N. Nzeribe *et al.*, "Physico-chemical processes for the treatment of per- and polyfluoroalkyl substances (PFAS): A review blossom," (2019), https://doi.org/10.1080/10643389.2018.1542916.

From laboratory to field – Water treatment and reuse in the food industry

Combination of innovative (plasma and ultrasound) with established technologies for the treatment of process water from agricultural industry. The technologies are studied under real-life conditions (currently sugar beet factory and brewery).



Project *Physics for Environment*

Features of the demonstration unit

- 20 ft shipping container
- Modular setup with adjustable order of treatment processes
- Automated operation and remote maintenance
- 0,3 – 2 m³/h throughput
- Approx. 5 kW of total power consumption

Fields of application

- Treatment of (waste-)water from agriculture and food industry
- Elimination of bacteria and pesticides
- Rain- and wastewater as alternative sources of process water for agriculture and food industry

➢ **Plasma is competitive but needs further development (scaling) to enter the market**

Applications of plasma technologies for water treatment and reuse

- Decentralized treatment of process and wastewater at „hotspots“ to remove recalcitrant pollutants
  - Hospitals, chemical and pharmaceutical industry, landfill leachate, …
- Treatment and reuse of process and wastewater
  - Aquacultures, hydroponics, food industry, laundries, …
- Rainwater as an alternative source for process and irrigation water
  - Agriculture, toilet flushing, …

Potential applications for plasma-based water treatment

Aquacultures

Hospital wastewater

Laundries

Landfill leachate

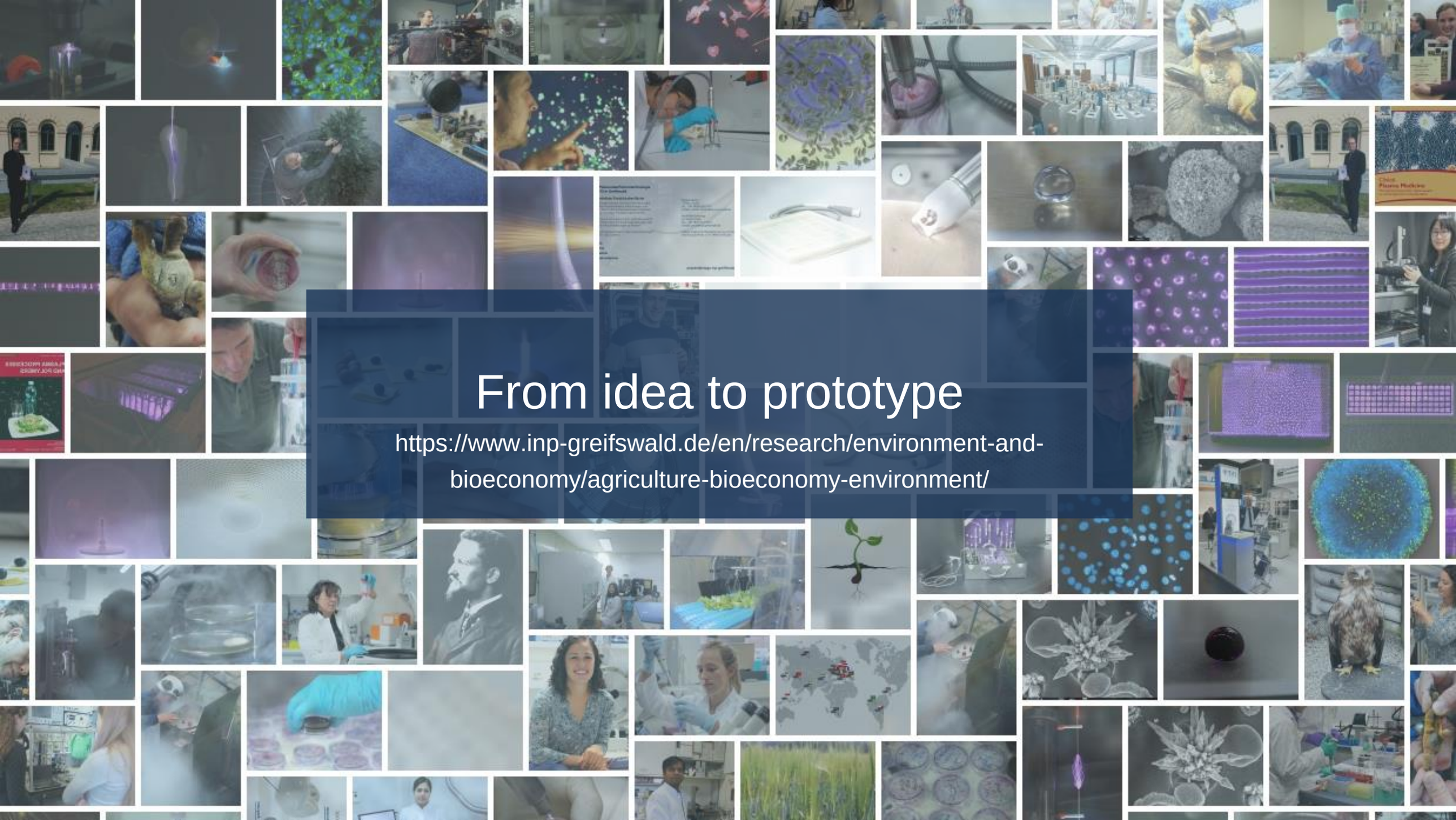
Wastewater

Rainwater

Plasma is a promising technology to achieve sustainable use of water

Elimination of biological and (persistent) chemical contaminants → **Reduction of environmental pollution**

Water reuse → Reduction of freshwater demand



From idea to prototype

https://www.inp-greifswald.de/en/research/environment-and-bioeconomy/agriculture-bioeconomy-environment/