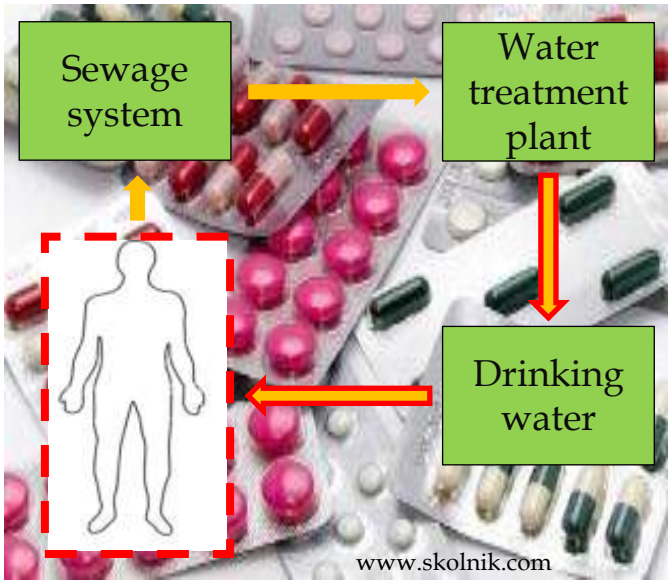
Underwater electrical discharges – removal of organic contaminants

Svetlana Gasanova
IWW Water Centre

Dublin
14th May 2013

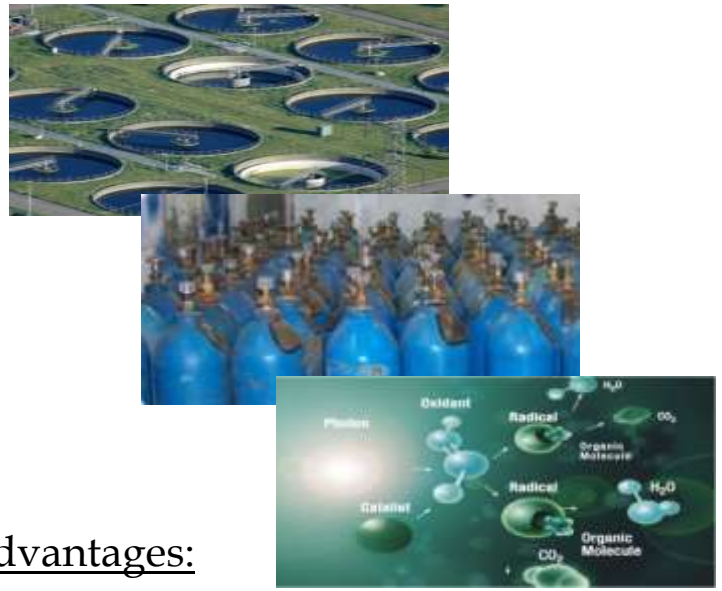
Background:
Threat of pharmaceuticals

- The increased consumption of pharmaceuticals
- Pharmaceuticals are not completely destroyed during the water treatment
- Accumulation of pharmaceuticals in human body



Background:
Water treatment techniques

- Biodegradation
- Ozonation & ozonation with UV
- Advanced Oxidation Processes (AOPs) – UV/H_2O_2, Fenton reaction



<u>Disadvantages:</u>

- Addition of chemicals
- Removal of the added substances and their recycling
- Incomplete degradation

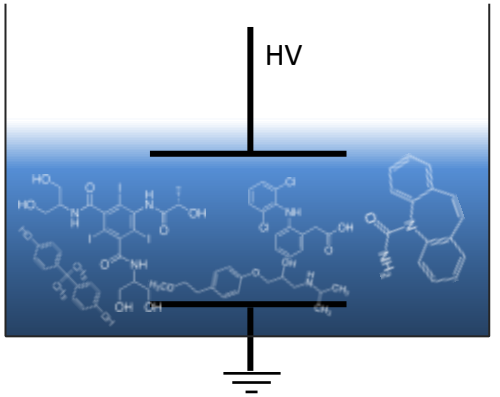
www.gazballon.ru, www.h2tronics.com, www.treatec21.com

Background:

Electrical discharges for water treatment

Physical effects:

- Strong shock waves
- Intense UV&Vis light emission
- Thermal effects



Chemical reactions:

- Formation of reactive species

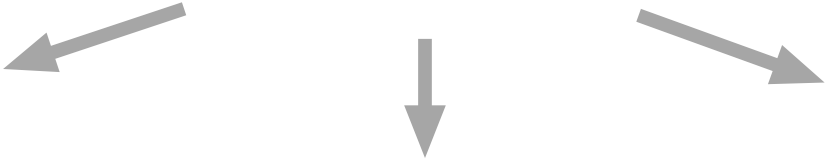
  in situ: OH, H, O radicals

Advantage:

- Chemical-free method
- Degradation of recalcitrant compounds

Aims

The aim of this project is to develop a chemical-free method of water treatment capable of degrading recalcitrant organic compounds.



Generation

Objective: reproducible underwater electrical discharge

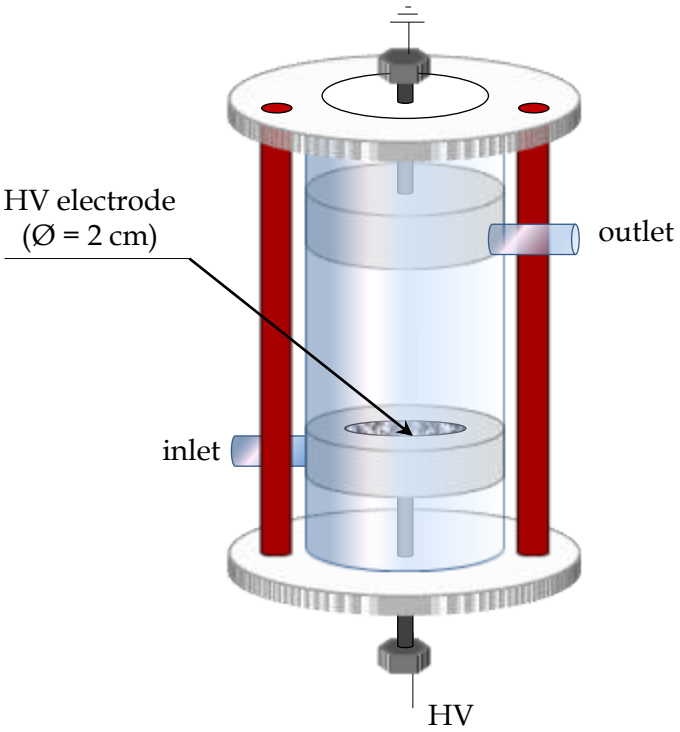
Diagnostics

Objective: Optimization of the obtained discharges

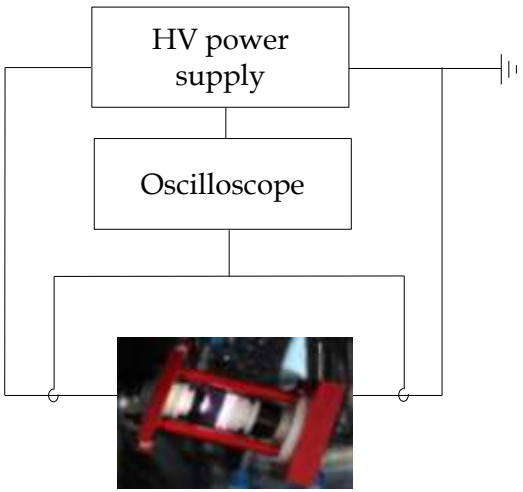
Application

Objective: Degradation of recalcitrant organics

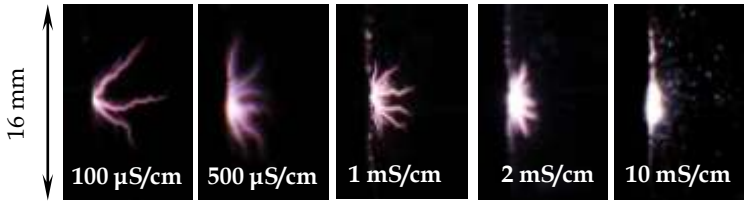
Electrical discharge generation

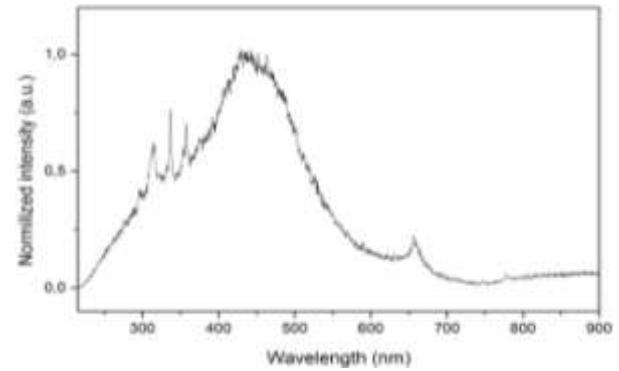


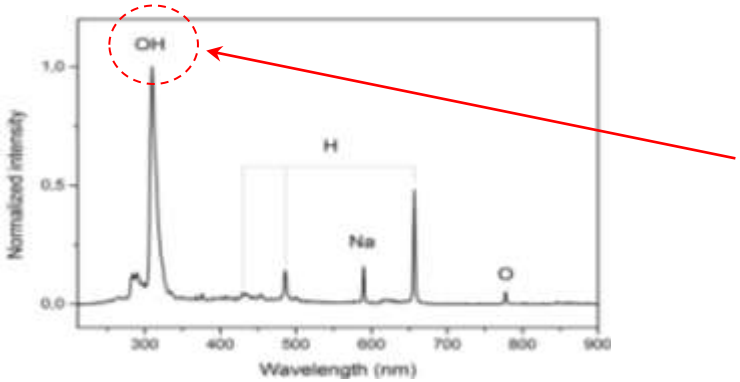
Parameter	Optimal values
Electrode coating	α-Al_2O_3, Pinholes (Ø 0.1 mm), 500 µm thick
Conductivity	2 mS/cm
Voltage	30 kV
Electrode gap	1.5 cm
Frequency	10 Hz
Current nature	Direct current
Pulse rise time	100 ns
Polarity	Positive polarity



Electrical discharge diagnostics







Discharge emission spectrum - Radiation of a blackbody:

- Visible region is important for the degradation of the compounds that undergo solar decomposition
- Near and Middle UV can be utilized for water disinfection
- Vacuum UV is responsible for the water photolysis (generation of hydroxyl radicals)

Emission spectrum of reactive species:

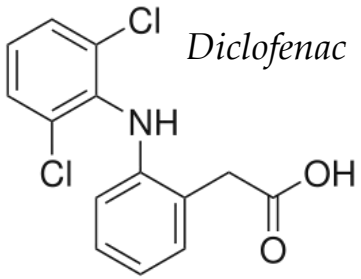
Formation of hydroxyl radical – a powerful, non-selective oxidant

($E_{red/ox}$ = 2.82 V)

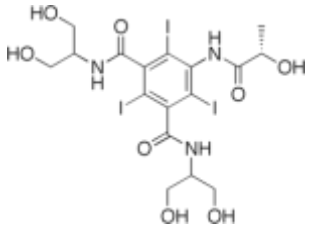
Application of electrical discharges:

Target compounds

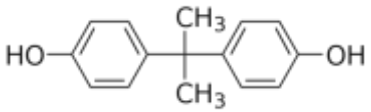
Diclofenac



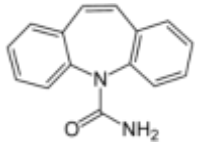
Iopamidol



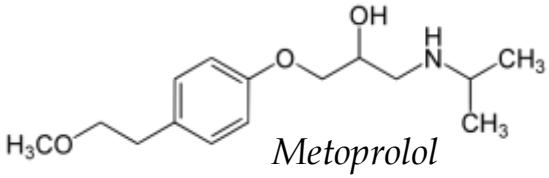
Bisphenol A



Carbamazepine



Metoprolol



Why?

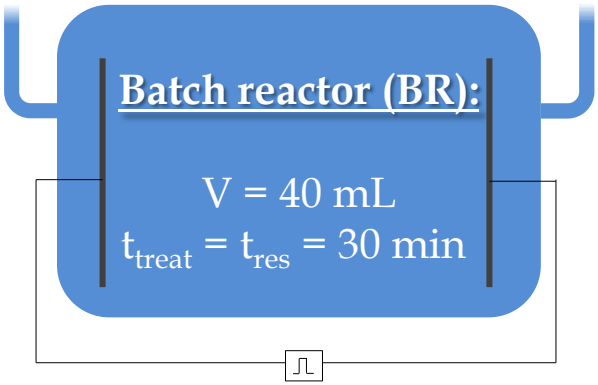
NTP technology is economically challenging ➡ To be used for really recalcitrant compounds ➡ **Pharmaceuticals** due to their pesistence in conventional water treatment

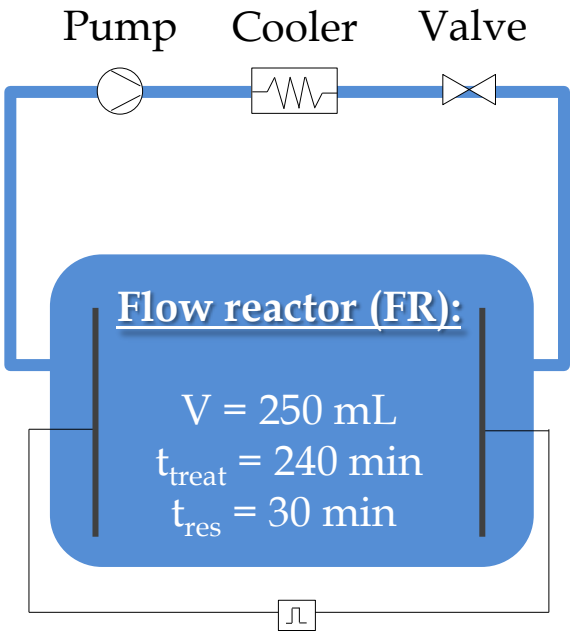
How?

UV/Vis light
Reactive species
Shock waves
High temperature

Degradation of organics:

Reactor types





- Smaller volume
- No mixing
- No cooling

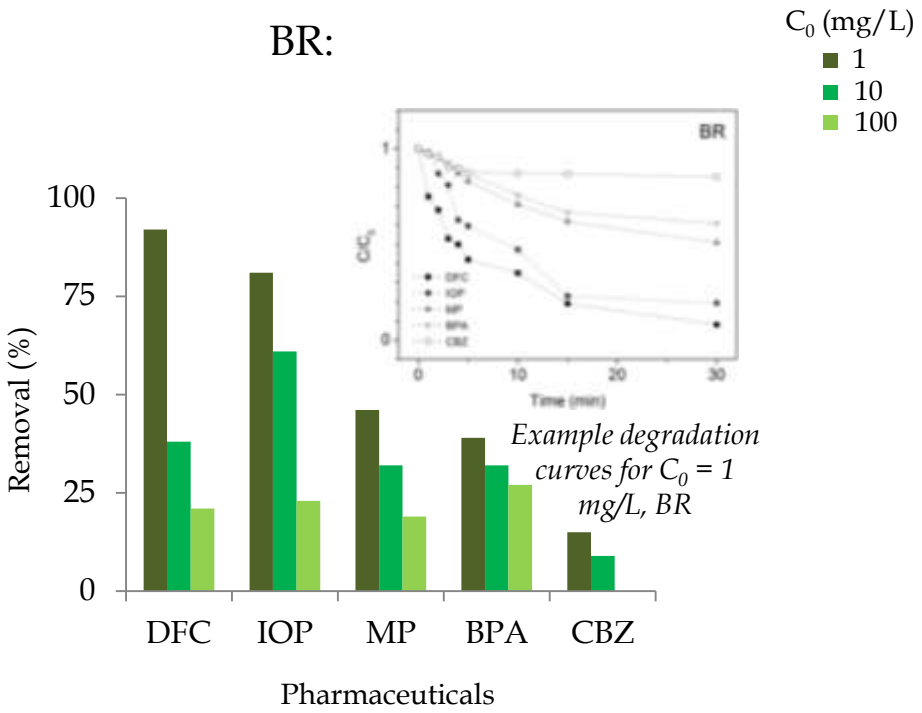
+ Shorter treatment time

+ Biger volume
+ Mixing
+ Cooling

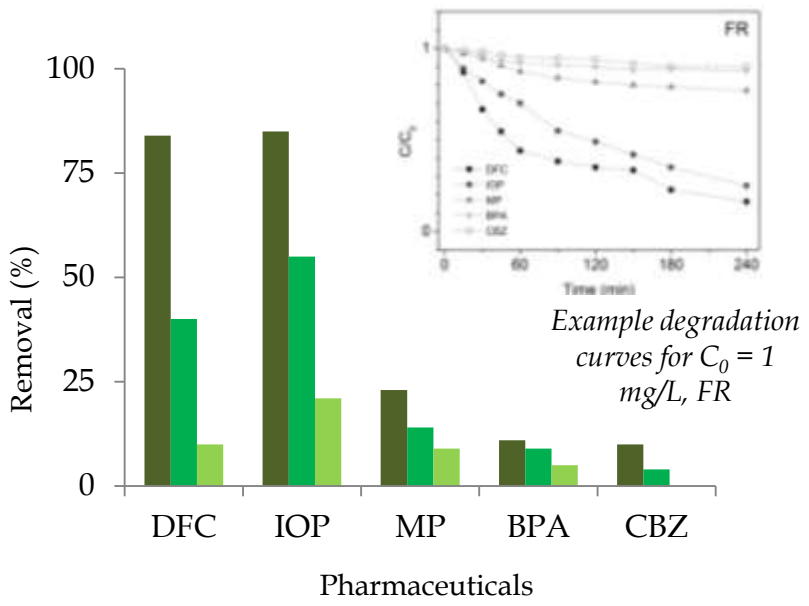
- Longer treatment time

Degradation of organics:
Removal rates

BR:



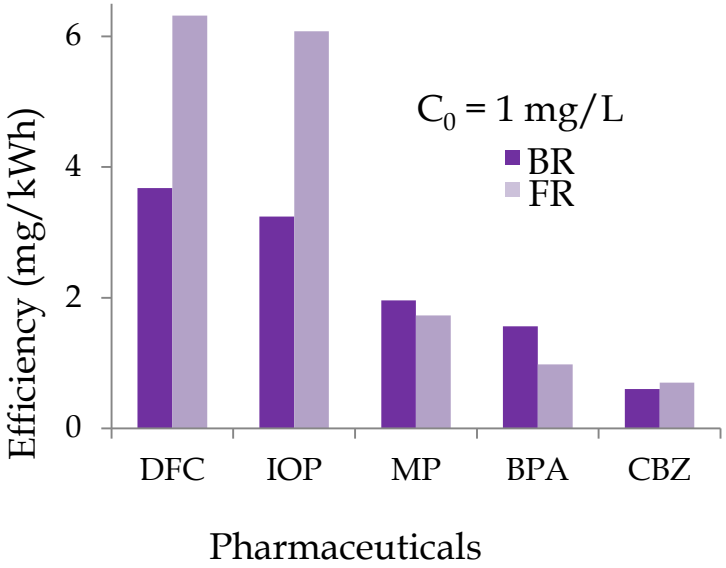
FR:

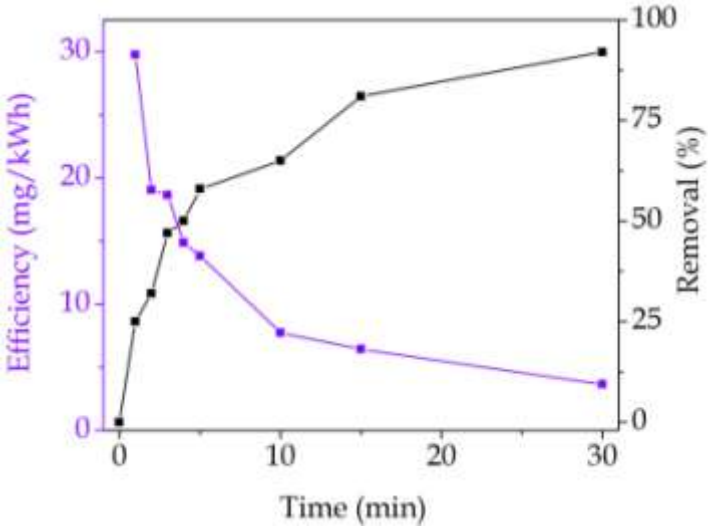


- Higher removal rates in the BR
- Higher removal rates for low initial concentrations

Removal efficiency

$$W = \frac{\text{the number of substance converted}}{\text{the required energy input}} = \frac{X \times C_0 \times V}{E_p \times F \times t}$$





Example of diclofenac degradation in a batch reactor, C_0 = 1 mg/L

Removal efficiency:

- in the range of a few mg/kWh (for C_0 = 1 mg/L)
- decreases with time => compromise between removal rates and efficiency

Summary

- Underwater electrical discharges have been proven to have a great potential to treat water
- No chemicals are involved in the water treatment process
- High removal rates for recalcitrant compounds have been achieved
- One can expect almost complete degradation in real samples (where C_0 is in the range of µg/L)

Outlook:

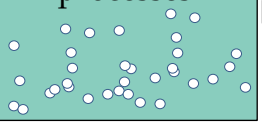
Implementation route

Influent: wastewater

Pretreatment
Large particles separation

Primary
Sedimentation, sludge digestion

Secondary
Aerobic biological processes



Tertiary

Underwater electrical discharges

Removal of specific contaminants, disinfection

Effluent: drinking water

Thank you for attention