Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Key objectives:

(1) developing procedures for efficient **decontamination of wastewater** of agricultural origin and for the **treatment of growth media (solid/liquid)** and manure;

(2) creating protocols for **productions of PAW (Plasma Activated Water)** defined by the type of application of PAW.

Work group 4 leaders:

Zdenko Machala (Comenius University, Bratislava, Slovakia) machala@fmph.uniba.sk

Wolfgang Gernjak (ICRA, Girona, Spain) wgernjak@icra.cat

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Work group tasks:

T4.1. Wastewater treatments and decontamination of water by atmospheric pressure LTPs:

- Water treatment processes based on non-thermal plasma combined with classical treatments (e.g. biological) for purification of wastewater contaminated with pollutants from agricultural practices or animal farms (pesticides, antibiotics, bacteria etc.).
- PAW: characterization of chemical and physical properties.
- Toxicity and ecotoxicity tests of the stable products remaining after plasma treatment.
- Developed procedures for plasma treatments compared to classical water treatment practices. If successful, classical (incl. AOT) procedures will be complemented by plasma treatments.

T4.2. Plasma treatment of water for creation of PAW:

- Atmospheric pressure LTPs for treatment of unpolluted water → PAW;
- Optimization procedures for treatments of water;
- Detailed chemical and physical characterization of PAW (HPLC, LC-MS, UV-Vis, etc.) with a special care given to the tests of a possible toxicity of PAW;
- Ageing effect of the PAW. Procedures for storing PAW will be determined and recommended for end users;
- This task will be performed in close relation to the tasks T2.1, T2.3. and T3.1.

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Work group tasks:

T4.3. Plasma assisted treatment of the plant growth media (soil, water) and manure/organic waste:

- LTP treatment of the plant growth media and manure for the fertilization purposes;
- Chemical and physical characteristics with the emphasis on bactericidal and fungicidal characteristics of the treated growth media;
- Possible toxic effects.

T4.4. Modelling and development of plasma systems for treatments of growth media:

- Characterization of plasma systems specific for wastewater treatment, growth media treatment and production of PAW: detailed diagnostics and modelling;
- Where possible, well characterized laboratory systems showing the best potential in applications will be turned into prototypes ready to be used by end users.

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Plasma applications for smart and sustainable agriculture

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

1st Work Group 4 online meeting (18-19 January 2021)

Mapping of R&D activities, expectations of workgroup contributors and alignment towards common objectives

https://teams.microsoft.com/l/team/19%3ae5ce612bd59048a29408b6dfeb4e5538%40thread.tacv2/conversations?groupId=92f2e3ff-57b6-46bc-bf6a-021143cdc7c6&tenantId=ce31478d-6e7a-4ce7-8670-a5b9d51884f9

Mon 18 January 2021

13:30-14:00	Session 1: Introduction		
	Nevena Puač	Institute of Physics, University of Belgrade, Serbia	**Introduction to PlAGRI COST Action**
	Zdenko Machala	Comenius University Bratislava, Slovakia	**Introduction to Work group 4**
	Wolfgang Gernjak	Catalan Institute for Water Research, Girona, Spain	**Introduction to meeting schedule and objectives**

14:00-14:45	Session 2: Expectations towards the technology and how WG4 should contribute and facilitate this progress		
	Wolfgang Gernjak (moderator)	Catalan Institute for Water Research, Girona, Spain	**Facilitated interactive session - expectations from WG4**

14:45-15:00 Coffee break

15:00-17:30	Session 3: Mapping of R&D activities - participant flash presentations		
	(Block I - Plasma-water chemistry)		
15:00-15:15	**Jan Benedikt**	Kiel University, Germany	**Plasma-generated O atoms transport into and reactivity with aqueous solutions**
15:00-15:15	**Zdenko Machala**	Comenius University Bratislava, Slovakia	**Plasma-water interactions – chemistry and transport of reactive species**
15:30-15:45	**Kinga Kutasi**	Wigner Research Centre for Physics, Budapest, Hungary	**Controlling the PAW composition by Fenton-type of ions**
15:45-16:00	**Yury Gorbanev**	University of Antwerp, Belgium	**Plasma-liquid interaction: how big is the role of liquid?**

16:00-16:15 Coffee break

	(Block II - Emerging water contaminants)		
16:15-16:30	**Chedly Tizaoui**	Swansea University, United Kingdom	**Non-thermal plasma for the removal of emerging contaminants in water**
16:30-16:45	**Bratislav Obradović**	University of Belgrade, Serbia	**Plasma treatment of water polluted by herbicides**
16:45-17:00	**Ester Marotta**	University of Padova, Italy	**Plasma remediation of PFAS contaminated water for use in irrigation**
17:00-17:15	**Arijana Filipić**	National Institute of Biology, Ljubljana, Slovenia	**Inactivation of viruses in water**
17:15-17:30	**Monica Magureanu**	National Inst. for Lasers, Plasma and Rad. Physics, Bucharest, Romania	**Brief history of the research on plasma treatment of water in NILPRP**

Tue 19 January 2021

9:00-11:00	**Session 4: Mapping of R&D activities - participant flash presentations**		
	(Block III - Agriculture / water treatment / PAW)		
9:00-9:15	**Fernando Alba-Elías, Yolanda Saenz**	University of La Rioja, Center for Biomedical Research of La Rioja, Spain	**PAW generation and applications: our research approach**
9:15-9:30	**Romolo Laurita**	Università di Bologna, Italy	**Plasma processes for PAW production under development at the University of Bologna**
9:30-9:45	**Petr Lukeš**	Institute of Plasma Physics, Prague, Czechia	**Research activities of IPP in the plasma treatment of water for applications in agriculture**
9:45-10:00	**David Duday**	Luxembourg Institute of Science and Technology	**Nanoparticles, plasma jets and mass spectrometry to improve the treatment of liquids**
10:00-10:15	**Wolfgang Gernjak**	Catalan Institute for Water Research, Girona, Spain	**Research activities in advanced oxidation technologies at ICRA**
10:15-10:30	Coffee break		

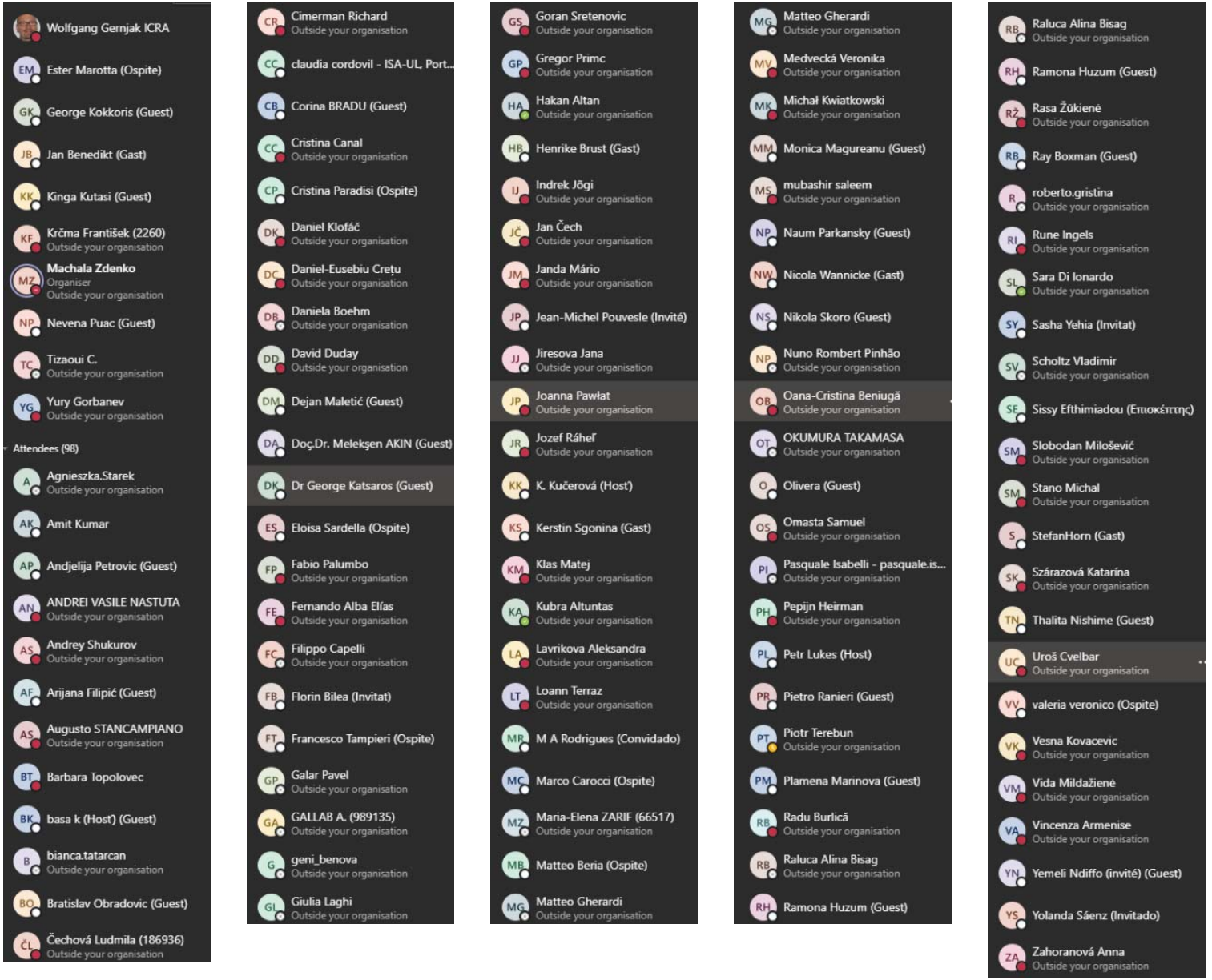
	(Block IV - Technology development)		
10:30-10:45	**George Kokkoris**	NCSR Demokritos, Athens, Greece	**Atmospheric pressure plasma jets: A lab-scale unit for PAW and fast computations of reactive species' densities in jets**
10:45-11:00	**Jan Čech**	Masaryk University, Brno, Czechia	**CaviPlasma – the new tool for energy-efficient large-scale PAW production**
11:00-11:15	**František Krčma**	Technical University, Brno, Czechia	**Pin-hole based systems for generation of plasmas in liquids**
11:15-11:30	**Nikola Skoro**	Institute of Physics, University of Belgrade, Serbia	**Treatment of pure and contaminated water by atmospheric pressure plasma**
11:30-11:45	**Luís Redondo**	EnergyPulse Systems, Lisboa, Portugal	**Solid-state pulse generators for ozone production**

11:45-12:00 Coffee break

12:00-13:00	**Session 5: Discussion on goals of WG4**		
12:00-12:10	**Zdenko Machala**	Comenius University Bratislava, Slovakia	**Wrap-up of day 1+2**
12:10-12:55	**Wolfgang Gernjak**	Catalan Institute for Water Research, Girona, Spain	**Faciliated discussion**
12:55-13:00	**Zdenko Machala**	Comenius University Bratislava, Slovakia	**Preliminary conclusions and next steps**

At 18/01/2021 15:30 CET

112 participants online!



Knowledge gaps – Water decontamination

Priority 1:

Toxicity and by-products
Scalability potential

Priority 2:

Understanding chemical interactions with contaminants and water matrix
Energy efficiency and standardized assessment

Others:

Difference in plasma sources
Reactive species characterization
Plasma characterization
Integration with other water treatment technologies
Kinetics, effect of concentration

Knowledge gaps – Plasma activated water generation

Priority 1:

Composition of PAW
Is it more economic than off-the-shelf chemicals
Relate plasma (“gas”) with PAW (liquid) properties
Scalability potential
Shelf-life

Priority 2:

Differences among power supplies
Standardized controls and reproducibility

Others:

What about PAW generation with high concentration of organics present?

Knowledge gaps – plasma assisted treatment of growth media

Priority 1:

Mechanism of action
Interaction with organic substances

Priority 2:

Scalability potential
Influence on soil microbioma
Transport in porous media, where does it “react”?

Technology barriers – water decontamination

Priority 1:

Energy consumption
Scalability
Economics

Priority 2:

Comparison with other technologies
Integration with other technologies
Acidity generated
Influence of plasma source
Manufacturing of plasma sources

Technology barriers – PAW generation

Priority 1:

Scalability
Economics

Priority 2:

Reproducibility, quality control

Technology barriers – Growth media

Priority 1:

Scalability
Site-specifics, soil characteristics

Priority 2:

Definition of applications (greenhouse?)
Economics

Regulatory and environmental compliance issues

Priority 1:

Toxicity, by-products (or even PAW ingredients)
Food legislation

Priority 2:

REACH
Biocide directive
Safety

Increase participation from:

Priority 1:

Biotech
Agronomists

Priority 2:

Industry and end-user
European Food Safety Authority
Microbiology (microbial communities)
Electrical engineers
Environmental engineers
RD offices of governments / agronomy ministries
Regulators and policy makers
Nanocharacterization

52 respondents listed 8 companies

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Tools

Q1: Knowledge generation, STM 8.53
Q2: Knowledge review and unification 8.57
Q3: Joint applications for R&D funding 8.30
Q4: Dissemination to the general public 7.79
Q5: Building the "plasma marketplace" 8.42

Gaps & Needs

- **Scalability**
- **Benchmarking efficiency and cost**
- **Toxicity & by-products**
- Interaction with organic substances
- Composition of PAW, Relate plasma ("gas") with PAW (liquid) properties
- PAW shelf-life
- Legislative voids
- Network extension
- Company and innovation canvas

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

1st PlAgri Training School, 17-19 March 2021, Jahorina, Bosnia **- Lectures related to WG4:**

- David Graves: **General talk about RONS**
- Petr Lukes: **Gas-liquid interface chemistry; Water chemistry, plasma-activated water characteristics**
- Frantisek Krcma: **Overview of plasma sources used with or in liquids; main characteristics, geometries**...(little bit of general stuff); results in the field
- Wolfgang Gernjak: **The role of chemically or physically induced redox processes in wastewater treatment**
- Ester Marotta: **Chemistry angle/reactions/relevant species/pathways focused on LC-MS diagnostics**

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Plasma applications for smart and sustainable agriculture

1st Workshop of the COST Action – Plasma applications for smart and sustainable agriculture, 2-3 September 2021, Magurele, Bucharest

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Plasma applications for smart and sustainable agriculture

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

1st Workshop of the COST Action – Plasma applications for smart and sustainable agriculture, 2-3 September 2021, Magurele, Bucharest **- Lectures related to WG4:**

- Z. Machala - **Reactive oxygen and nitrogen species in plasma activated water: tuning their concentrations and functions in plant growth promotion**
- E. Marotta - **Plasma-based water treatment in agricultural applications**
- F. Bilea - **Removal of mixtures of pharmaceutical pollutants in aqueous solutions using non-thermal plasma**
- P. Brault - **Energy decomposition analysis of organic pollutants in water**
- A.V. Nastuta - **Tailoring plasma sources towards plasma agriculture: at the interface with liquids and solids**
- A. Bertaccini - **Plasma activated water as disease resistance inducer in plants**

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Running COST STS missions related to WG4 (Oct 2020-Oct 2021):

- Gervais Blondel Ndiffo Yemeli, Comenius University (Bratislava, Slovakia), to National Institute for Laser, Plasma and Radiation Physics, Magurele, Romania, 18.7. - 16.10., *Investigations of the effects of wastewater treated by non-thermal plasma on early seed germination and plant seedlings growth*

- Ludmila Čechová, Brno University of Technology (Brno, Czech Republic), to University of Padova, Italy, 19.9 - 17.10., *The influence of plasma and plasma activated water on cultivation media*

- Bianca Tatarcan, Alexandru Ioan Cuza University of Iasi (Iasi, Romania) to Comenius University Bratislava, Slovakia, *3–17 October 2021 – Assessment of long lived RONS in liquids after exposure to helium and air atmospheric pressure plasmas*

WG4 Deliverables according to MOU:

Month 10: LTPs in treatment of wastewater, growth media and PAW production

(Applications of atmospheric pressure plasma sources in treatment of wastewater, growth media and PAW production)

Month 30: Characterisation and optimisation of LTP applications: production of PAW, wastewater, growth media

(Internal report on the characteristics of the most efficient plasma sources, optimisation-modelling and diagnostics; Toxicity tests of treated media used for application with plants or re-usage for irrigation)

Month 46: Development of laboratory prototypes – water and growth media

(Development of prototypes of most efficient plasma systems for decontaminating of water, production of PAW and treatment of growth media; Guideline for scaling up of the systems)

Work group 4	Plasma treatment of agricultural wastewater, growth media, manure and production of plasma activated water (PAW)

Future plan:

- **Common review article(s)** on ***LTPs in treatment of wastewater, growth media and PAW production*** – 2nd year
  to make more mutual benefit of the COST WG4 report (M10 deliverable)

- Similar to *P J Bruggeman, M J Kushner, B R Locke, et al. : Plasma–liquid interactions: a review and roadmap, Plasma Sources Sci. Technol. 25 (2016) 053002 (59pp),* highly cited in WoS
  (result of COST TD1208 (2013-17)

- Face-to-face **2nd Workshop of the COST Action** (Slovakia, Sep 2022, associated with 9th Central European Symposium on Plasma Chemistry)

- Common project proposals (Horizon EU etc.)