# H2020 project ELECTRA "Electricity Driven Low Energy and Chemical Input Technology for Accelerated Bioremediation"

## *Highlights of ELECTRA technologies*

ELECTRA is a flagship project of the EU-China Cooperation Initiative. It is a 4-year Research and Innovation Action. The consortium consists of 16 European partners receiving funding from the European Union H2020 programme, and 5 Chinese partners being funded by the National Natural Science Foundation of China (NSFC).

We work closely together on the development and implementation of bio-electrochemical systems for the bioremediation of contaminated wastewater, groundwater, sediments, and soil. In the second newsletter, we are glad to present the technologies that ELECTRA partners have been developing over the past four years and the four technologies that have proceeded to pilot demonstrations are identified.

## EU– China Collaboration in the COVID-19 era

Despite difficulties imposed by the COVID-19 pandemic, the European and Chinese partners of ELECTRA were able to set multiple scientific and technological collaborations, which have materialised in eleven joint publications and an oral communication. Most importantly, scientific missions of young Chinese researchers in the labs of European partners and reciprocally already took place. Three Chinese students visited European labs for research stays and six European students attended one highlight event in China, namely workshop for European and Chinese BSc., MSc., PhD and post-docs working in the ELECTRA project. Unfortunately, during the past 24 months due to stringent travel restrictions in China, no more exchanges were materialized.

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Funded by the National Natural Science Foundation of China & Funded by the Horizon 2020 Framework Programme of the European Union

## *Groundwater denitrification by fluidized-bed bio-electrochemical systems (BES)*

At Gent University, we aim at developing fluidized-bed BES that can minimize the fouling issues on the fixed-bed cathodes and with a higher potential for up-scaling. It is important to find biofilms or conductive electrode materials with charge storage capacity, which allows continuous electron supply during fluidization. Thus, two approaches were investigated to explore the nitrate removal performance and the charge storage capacity in the BES. First, periodic polarization was applied to a fixed bed reactor, to mimic the intermittent electron transfer as the cathode was fluidized (study 1). Second, different cathodic materials were tested in a fluidized reactor to determine the optimal condition for maximized nitrate removal rate (study 2).

*Figure 1: Picture of lab-scale MECs for groundwater denitrification*

### Periodic polarization vs. continuous polarization in fixed-bed BESs

Two identical fixed-bed BESs (R1 and R2) were operated in parallel for nitrate removal from synthetic groundwater (Figure 1). R1 was operated under continuous polarization mode with cathode potential at -0.4 V vs.Ag/AgCl. R2 was operated under periodic polarization mode with 30s polarization at the same cathode potential and 30s open circuit (OCP). The continuously polarized R1 was able to fully remove 98% nitrate at a maximum rate of around 233 g $NO_3^-$-N /$m^3$/d. The periodically polarized R2 could reach maximum performance with 86% nitrate removal at a rate of around 200 g $NO_3^-$-N /$m^3$/d. In the majority of the operational time, less than 10 mg $NO_3^-$-N /L remained in the effluent from both MECs when the anolyte was manually refreshed, which was below the nitrate concentration standard in drinking water.

The polarization modes of R1 and R2 were alternated for 3 days after day 386, then swopped back. Regardless of the long-term (over a year) polarization mode of the biofilms, around 10% more nitrate was removed by continuous polarization than by periodic polarization in each reactor. Under continuous polarization mode, the biofilms in R2 (with long-term periodic polarization) were able to remove around 14% more nitrate than the EABs in R1 (with long-term continuous polarization), and a similar result was obtained under periodic polarization mode. Thus, the highest denitrification rate 221.8 ± 0.3 g/$m^3$/d with 93% nitrate removal was observed in R2 under continuous polarization using the biofilms that were previously periodically polarized for a long term. Under periodic polarization, the faradaic charge in R2 was 1.4 times as much as in R1, however, the

capacitive charge in R2 was 9 times as much as in R1. Those results suggested that the long-term periodic polarization in R2 may have increased its charge-storing capacity and ability to uptake faster electrons when available.

### Compare different cathodic materials for nitrate removal in fluidized-bed BES

The same reactor set-up as in study 1 was applied with different cathodic materials: C1 was filled with 60 ml activated carbon (AC) particles (1/3 of the cathodic chamber volume); C2 was filled with 60 ml vitreous carbon (VC) particles. At the same recirculation rate (19 L/h), the AC in C1 was less fluidized compared to the VC in C2, due to the larger particle size of AC. To optimize the nitrate removal performance, the HRT was gradually decreased by increasing the feeding rate. In C1, the HRT was decreased in three steps, 10.7 h, 6.5 h, and 5.3 h, with the feeding rate 0.45 L/d, 0.74 L/d and 0.9 L/d, respectively. In C2, the HRT changed from 8.0 h, to 6.2 h and 5.1h, while the feeding rate increased from 0.6 L/d to 0.77 L/d and 0.95 L/d. Chronoamperometry was applied to both reactor with gradually decrease cathodic potentials (186 days in C1 and 182 days in C2).

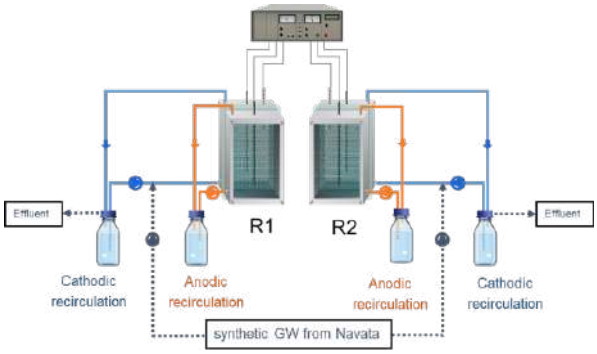


*Figure 2: Sketch of the MECs operation*

In C1 with AC as the cathode, the nitrate concentration in the effluent was less than 10 mg $NO_3^-$-N/L under each operational condition applied, which is below the standard for drinking water. The denitrification rate increased over time, with increasing feeding rate and more electricity input. The highest denitrification rate 136.72 ± 6.86 g $NO_3^-$-N/$m^3$/d was reached with 93% nitrate removal and 94% coulombic efficiency. In C2 with VC as the cathode, nitrate concentration in the effluent was below 10 mg $NO_3^-$-N/L till day 155, then increased even with a more negative cathodic potential applied. The main reason was the decomposition of VC due to the friction between particles in a fluidized-bed mode. The effluent turned blackish with time and the biofilms might be washed out gradually with the small particles in the effluent. In addition, the recirculation tubes were blocked with particles thus leaking occurred. The highest denitrification rate reached 102.21 ± 5.69 g $NO_3^-$-N/$m^3$/d (feeding rate 0.77 L/d, cathodic potential -1.1 V ), with around 85% nitrate removal and nearly 100% coulombic efficiency.

In the first 75 days of the continuous feeding period, the fluidized-bed C2 with VC as the cathode showed slightly better nitrate removal performance, in terms of lower nitrate concentration in the effluent, higher denitrification rate and coulombic efficiency, and lower energy consumption, compared to the fixed-bed C1 with AC as the cathode. The denitrification performance and cathodic materials need to be further optimized in order to achieve the target in fluidized-bed BES.

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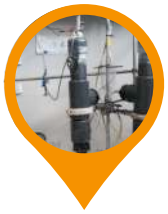
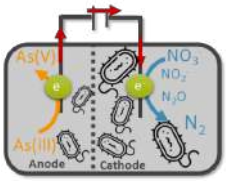
# *Nitrate electro-bioremediation: A fixed-bed bio-electrochemical reactor able to remove nitrate by electricity input and no chemicals dosage*

## Laboratory scale



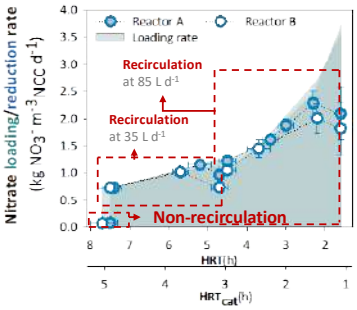



Ceballos-Escalera, A., et al., (2021). Water Res. , 190

**HIGH $NO_3^-$ REMOVAL RATE**
2.3 ± 0.2 Kg $m^{-3}$ $d^{-1}$
5.0 ± 0.3 Kg $m^{-3}$ $d^{-1}$

**CO-POLLUTANTS REMOVAL**
95% As(III) oxidation to As(V)

**EFFLUENT QUALITY**

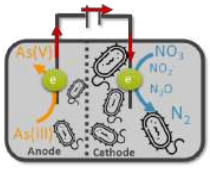



**Standard drinking water quality** in terms of nitrate and nitrite concentration accomplished
*(Nitrates Directive, 91/767/EU)*

**Ecotoxicity tests with different organisms**
*Sinapis alba, Triticum aestvum, Tetrahymena pyriformis* and *Daphnia magna*

Non-toxic effect

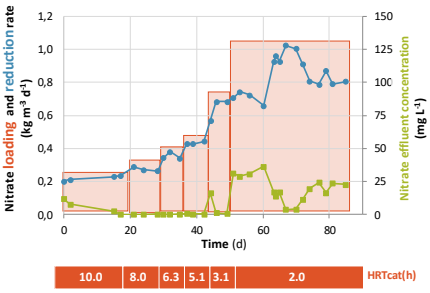
## On-site pilot plant




**HIGH $NO_3^-$ REMOVAL RATE**
0.9 ± 0.1 Kg $m^{-3}$ $d^{-1}$

**ENERGY-EFFICIENT**
0.31 ± 0.03 kW $m^{-3}_{water}$

**EFFLUENT QUALITY**

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*Sinapis alba, Triticum aestvum, Tetrahymena pyriformis* and *Daphnia magna*

Non-toxic effect

Universitat de Girona
lequia ECO-INNOVATIVE WATER SOLUTIONS UdG

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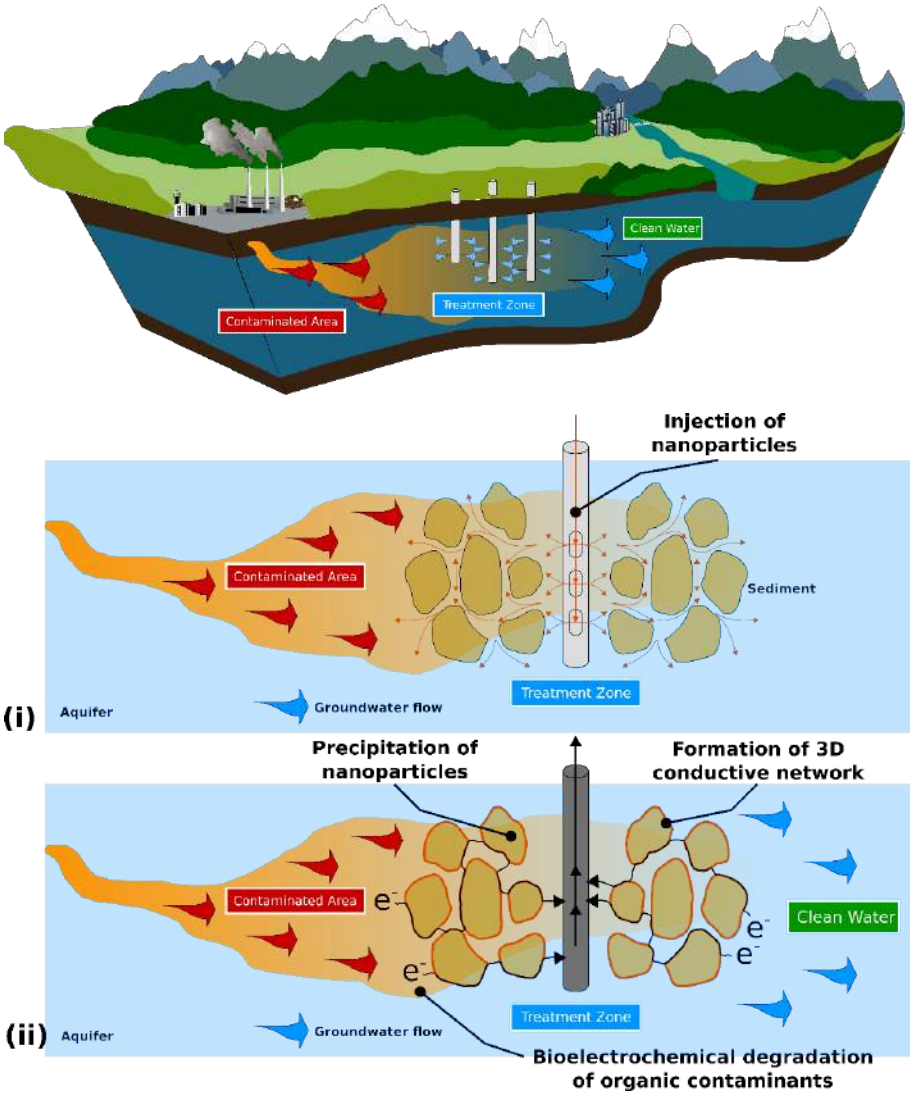
## *Bio-reactive barrier using conductive nanoparticles*

The electron acceptors often limit the microbial degradation of pollutants in the environment. This can be improved by the direct interaction of microorganisms with a solid-state electron acceptor in form of an electrode (Anode). We develop an *in situ* bioremediation process using conductive nanomaterials for the bioelectrochemical removal of contaminants, e.g. polycyclic aromatic hydrocarbons (PAHs) by enhancing the anaerobic degradation.

Bio-reactive barriers: an in-situ remediation process using electrodes and conductive nanoparticles for bioelectrochemical removal of heavy metals and organic pollutants in sediments. Nanoparticles are injected into the sediment, where they precipitate and lead to increased electrical conductivity and to an enlargement of the active electrode surface.

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## *The IRSA-CNR"Bioelectric Well": A groundbreaking technology for the treatment of groundwater containing complex mixtures of contaminants*

The presence of petroleum hydrocarbons (PHs) in groundwater is mostly caused by accidental spills and industrial discharges, and it represents a critical threat to human health and the ecosystem. Due to their high mobility and water solubility, benzene, toluene, ethyl-benzene and xylenes (BTEX) are particularly dangerous when dispersed in the environment, often amounting up to 90% of the dissolved pollutants in groundwater contamination plumes. Notably, PH are often present in groundwater along with other harmful contaminants such as the chlorinated aliphatic hydrocarbons (CAH).

Bioremediation of groundwater contaminated by a mixture of PH and CAH is typically challenged because these contaminants are degraded via distinctive oxidative and reductive pathways, thus requiring different amendments and redox conditions.

In recent years, microbial electrochemical technologies (METs) have emerged as a novel and highly versatile platform for treating soils and groundwater contaminated by either PH or CAH. METs employ electroactive microorganisms to electro-catalyze oxidation or reduction reactions using solid-state electrodes as virtually inexhaustible electron acceptors or donors. In previous studies, METs have been successfully employed to stimulate the oxidative treatment of groundwater containing PH such as benzene, toluene, xylenes, and ethyl-benzene (BTEX), as well as the reductive dechlorination of a variety of CAH, including perchloroethene (PCE), trichloroethene (TCE), and 1,2,-dichloroethane (1,2-DCA).

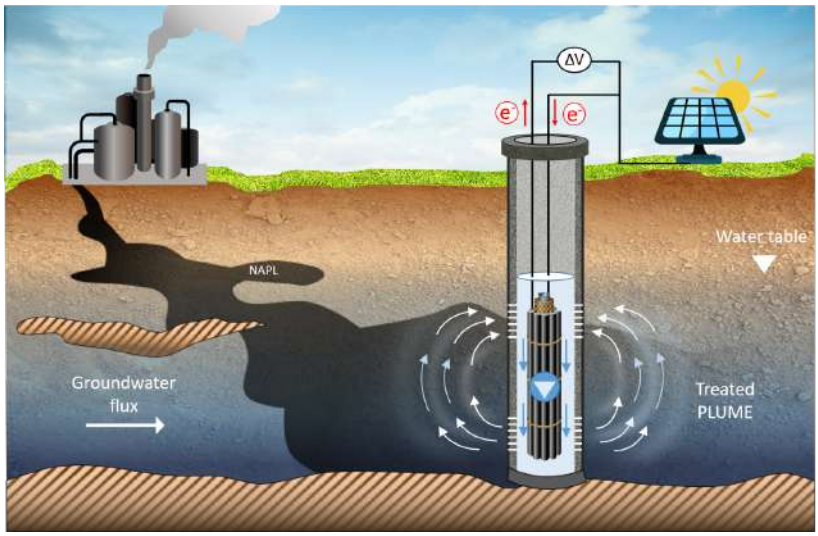


*Figure 3: Schematic representation of the Bioelectric Well mode of operation*

In this context, IRSA-CNR has recently developed a novel tubular bioelectrochemical reactor, specifically designed for *in situ* treatment of contaminated groundwater, named "Bioelectric Well" (Figure 1). Due to its unique design and characteristics the Bioelectric well can be employed for a single-stage treatment of groundwater containing complex mixtures of both oxidizable (e.g., PH) and reducible (e.g., CAH) contaminants.

## Main findings

In the frame of the ELECTRA H2020 Project, a lab-scale prototype of the Bioelectric Well (Figure 2A) has been developed which consisted of a cylindrical anode made of 8 contiguous graphite rods (purity: 99.995 %, length: 30 cm, ø: 0.6 cm; Sigma-Aldrich, Italy) and a stainless-steel mesh cathode (dimensions: 3 × 30 cm; type 304, Alpha Aesar, USA) which were concentrically placed within a 250 mL glass cylinder. Anode and cathode were kept physically separated by a polyethylene mesh (ø: 1 cm, length 30 cm), which still allo wed hydraulic connection. The anode was continuously polarized at +0.2 V vs. SHE, using a potentiostat (IVIUMnSTAT, IVIUM Technologies, The Netherlands), while the cathode was used as counter electrode. An Ag/AgCl electrode (KCl sat., +0.198 V vs. SHE; AMEL, Italy) was used as the reference electrode.

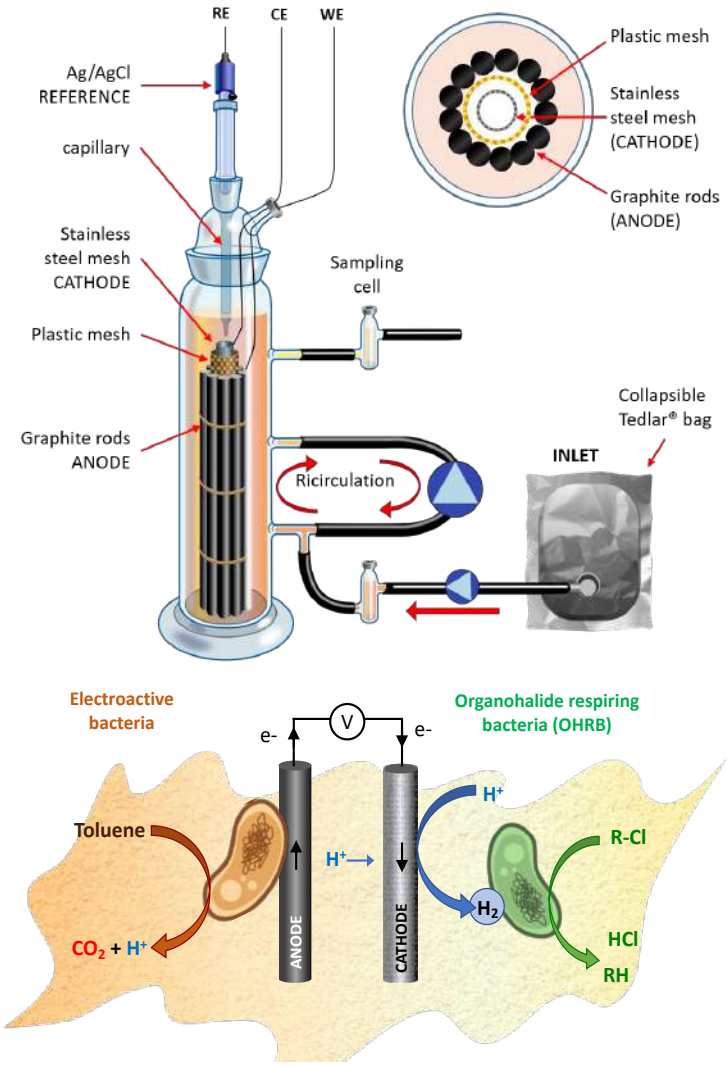


*Figure 4: Schematic drawing of the lab-scale prototype of bioelectric well (A). Schematic representation of anodic and cathodic reactors.*

Throughout the study the reactor was operated under a broad range of conditions, for the treatment of commingled PH/CAH groundwater. As an example, when the reactor was fed with synthetic groundwater containing a mixture of toluene and TCE, an electric current (up to nearly 1 mA) was produced from the microbially-catalyzed oxidation of toluene (with a maximum observed removal rate of 150 µmol/L d). This latter resulted in (abiotic) hydrogen production (at a stainless-steel cathode), which in turn sustained the reductive dechlorination of TCE to less-chlorinated intermediates (i.e., cis-DCE, VC, and ETH), at a maximum rate of 500 µeq/L d.

Overall, the obtained results convincingly demonstrate that anodic and cathodic processes can be simultaneously exploited within an ad hoc designed bioelectrochemical reactor for the treatment of problematic groundwater containing a mixture of oxidizable and reducible contaminants.

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## The IRSA-CNR "Microbial Electrochemical Snorkel": A passive biotechnology for the cleanup of contaminated soils

The microbial electrochemical snorkel concept aims to improve the biodegradation potential, while minimizing the associated energy footprint, of conventional ex situ soil treatment technologies (e.g., landfarming and biopiling).

The system consists of a conductive graphite rod (the 'snorkel') positioned for electrochemically connecting two spatially segregated redox zones: the anoxic contaminated soil/sediment and the oxic ($O_2$-containing) overlying water (Figure 1). The portion of the snorkel positioned in the anoxic soil/sediment serves as an electron acceptor (i.e., an anode), sinking electrons deriving directly from the microbially catalysed anaerobic oxidation of contaminants and from the chemical and/or biochemical oxidation of reduced species (i.e., sulphide, ferrous ion) occurring in the bulk of the soil/sediment. Upon transfer to the buried portion of the snorkel, the electrons move to the upper portion (i.e., the cathode), driven by the existing redox gradient, where they combine with oxygen and protons to form water as a by-product. The snorkel serves as a virtually inexhaustible respiratory electron acceptor in the anaerobic oxidation of oxidizable contaminants.

Four different treatments were setup, namely: 1) Snorkel treatment; 2) Control treatment (without snorkel); 3) Snorkel treatment with soil supplemented with conductive biochar particles (5 % w/w); 4) Control treatment (without snorkel) with soil supplemented with conductive biochar particles (5 % w/w). Biochar was used as conductor to possibly construct a conductive network with microbes in the soil matrix, thereby extending the radius-of-influence of the snorkel (Figure 5).

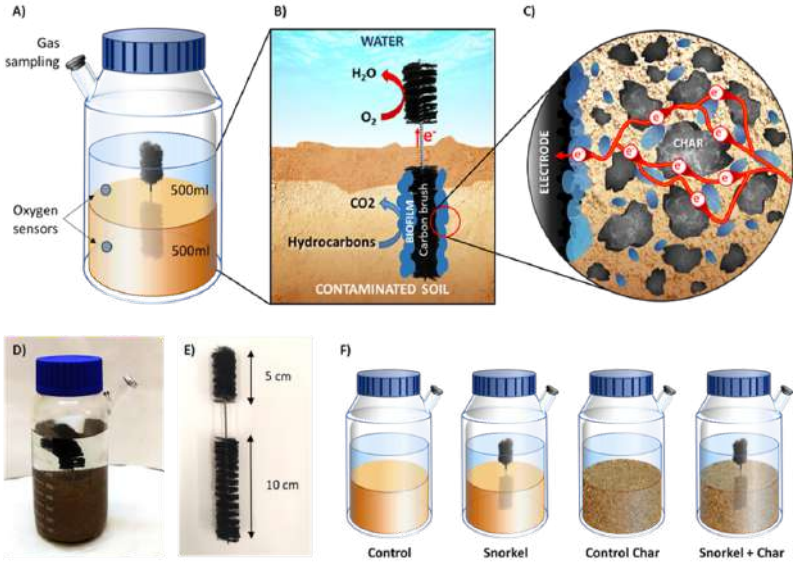


*Figure 5: A) Scheme of the reactor setup used in this study; B) Illustration of the soil MES concept; C) Illustration of the electron transfer process in a MES amended with biochar; D) Picture of the bottles used in the microcosm study; E) Picture of the carbon brushes used in the microcosm study; F) Scheme of the microcosm experimental setup.*

The addition of electrically conductive biochar particles has accelerated the biodegradation of petroleum hydrocarbons (mainly PAH) and reduced soil toxicity, relative to unamended controls. For almost all PAH, a greater

and accelerated removal was observed in treatments amended with biochar: 98–99 % vs. 75–80 % of removal in treatments with and without biochar, respectively (Figure 6).

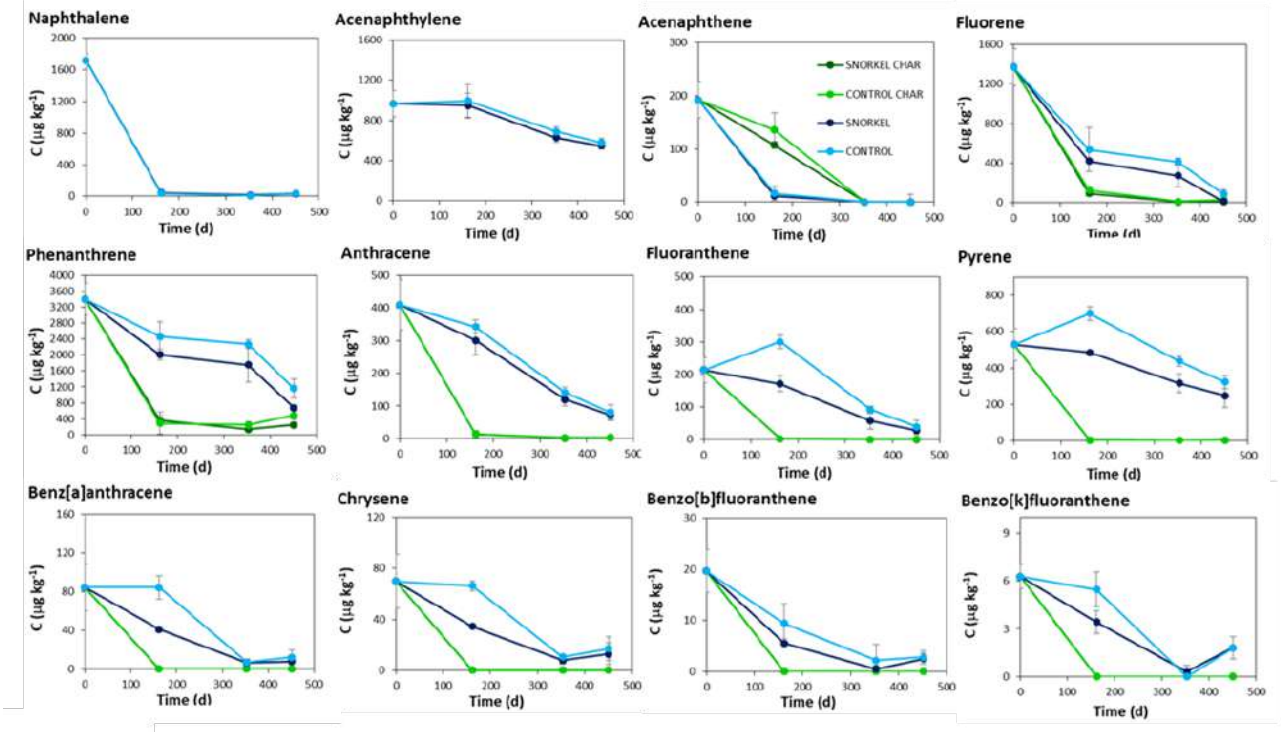


*Figure 6: Individual trends of concentration of the priority PAH pollutants detected in the soil versus time in the different treatments.*

By contrast, the application of a MES, either in the presence or in the absence of biochar, did not accelerate contaminants degradation. Adsorption of PAH over the biochar surface may have played a role in accelerating biodegradation (i.e., by allowing an effective colocalization of the contaminant and of the degrading-microorganisms possibly promoting syntrophic and/or cooperative anaerobic biodegradation processes).

Enhancement of biodegradation was mirrored by an increased abundance of aerobic and anaerobic microorganisms involved in the degradation of PH and related functional genes.

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## Field site study on groundwater remediation

In the context of the ELECTRA, project partners IEC and Sapienza University of Rome combined a Groundwater Circulation Well (IEG-GCW®) system and a reductive/oxidative bioelectrochemical sequential process for CAHs removal developed by University of Rome, La Sapienza, in a field test.

A former chemical facility located in the Rho district (Milano, Italy), was identified as the origin of a large chlorinated solvent plume. The highly contaminated source area was encapsulated by bulkheads in the 80s but it seems that there is still a leakage of pollutants from the isolated area to the deeper aquifer, caused by inhomogeneities in the underground. The vertical encapsulation system was set in a thin horizontal clay/sandy silt layer (about 1 – 2 m thick) which separates an upper shallow aquifer (5 to 10 m below ground) from a deeper one (12 to 40 m below ground). The groundwater samples from the shallow aquifer show high concentrations of trichloroethene (TCE) and *cis*-1,2-dichloroethene (*c*DCE) and some traces of vinyl chloride, in the deeper one the concentration levels decrease. It is planned to test a bioelectrochemical system of the University of Roma (Sapienza). For this purpose, IEG will install an IEG-GCW® system in the shallow aquifer ( Figure 8). The GCW system consists of a lower screen section followed by a hydraulically inactive zone (packer) and an upper screen section. A submerged pump extracts the groundwater from the lower screen section and infiltrates in the upper screen section. The resulting hydraulic gradient generates a groundwater circulation from the top of the aquifer to its base. Pollutants in the circulation zone will be mobilised and flow to the well for treatment. In industrial remediation projects, the IEG-GCW® is typically combined with treatment units like vacuum stripping and/or adsorption, *etc*. In other cases, amendments will be infiltrated and distributed for reductive dehalogenation of

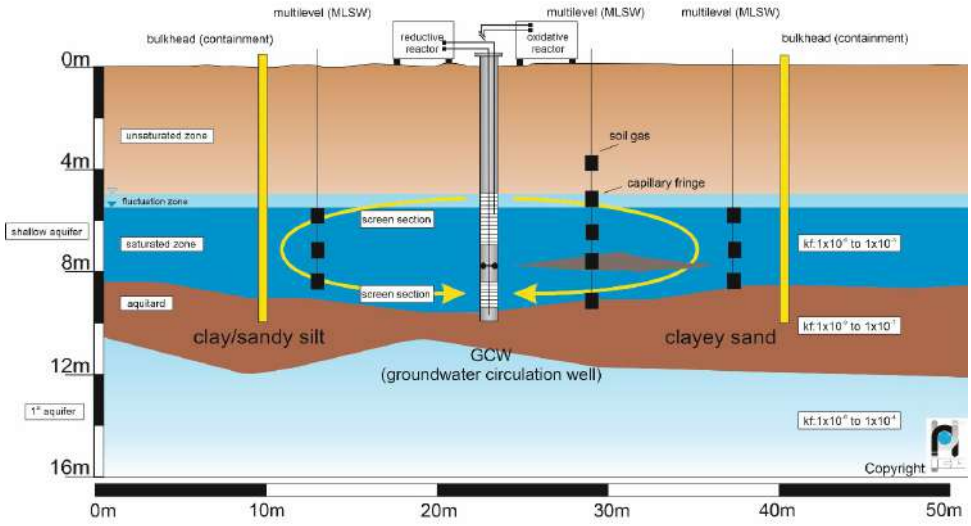


*Figure 7: Schematic field installation layout*

solvents. At the Rho site, a certain amount of the circulating water will be treated by an innovative reductive/oxidative bioelectrochemical sequential process under real remediation conditions.

The sequential bioelectrochemical process consisted of two separate tubular reactors which adopt a novel reactor configuration that avoids the use of an ion exchange membrane to separate the anodic and cathodic chamber (Figure 8). In the reductive reactor, a dechlorinating mixed inoculum received the reducing power to perform the reductive dechlorination of highly chlorinated aliphatic compounds by the cathode chamber while the less chlorinated daughter products (*c*DCE and VC) were removed in the oxidative reactor which supports an aerobic dechlorinating culture by *in-situ* electrochemical oxygen evolution performed by a mixed metal oxide anode. The separation of the reductive and the oxidative bioelectrochemical reaction allow the optimisation of the operating condition for each step such as the working potential and the hydraulic retention time.

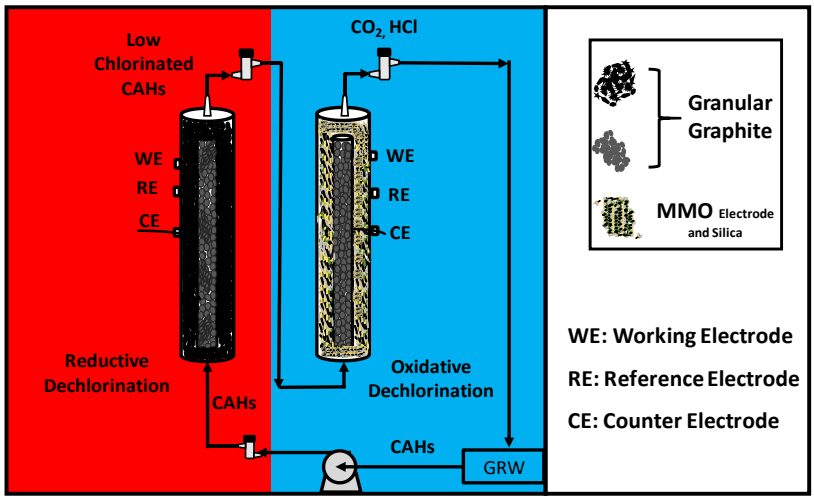


*Figure 8: Schematic representation of the sequential reductive/oxidative bioelectrochemical process*

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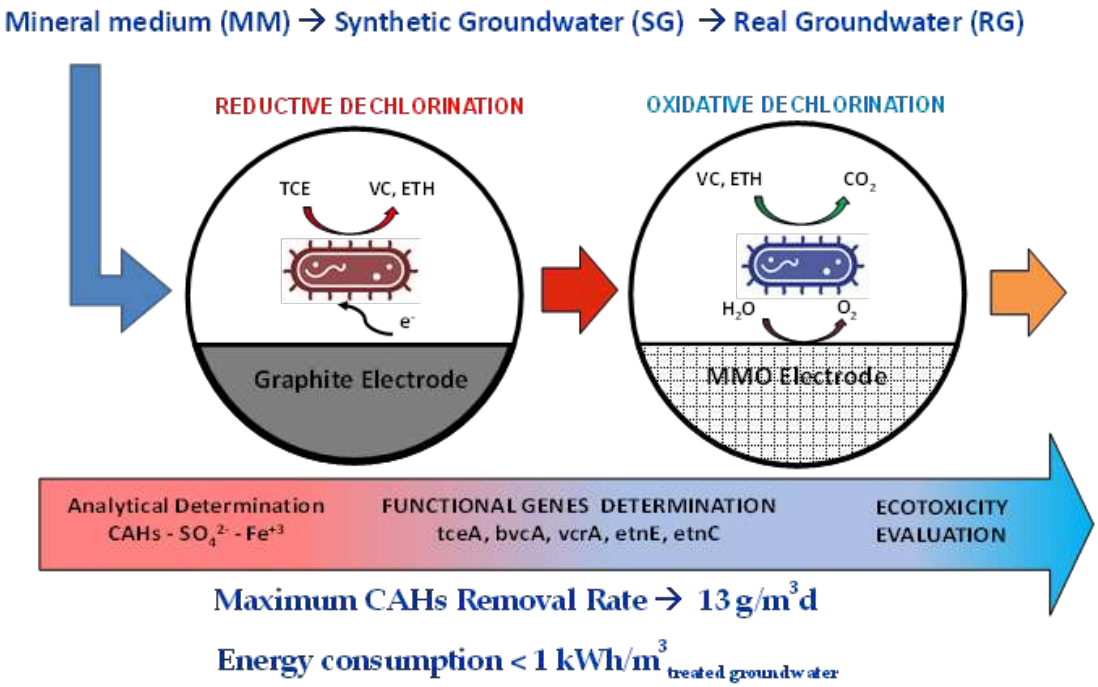
# Sequential cathode/anode treatment for groundwater remediation




## Main results

- Complete mineralization of the target compounds in all the explored feeding solutions
- Identification of the best operating conditions for the control of side reactions and energy consumption
- Validation of the technology with a real contaminated groundwater
- Groundwater ecotoxicity decrease after the sequential bio-electrochemical treatment
- Identification of the functional genes and microbial species involved in the reductive and oxidative reactions in all the tested feeding solutions

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# *Alternately polarized electrodes for PCB-polluted marine sediments remediation*

A bioelectrochemical system to stimulate *in situ* reductive dechlorination of PCBs in marine sediments has been investigated by the UNIBO team.

## Approach

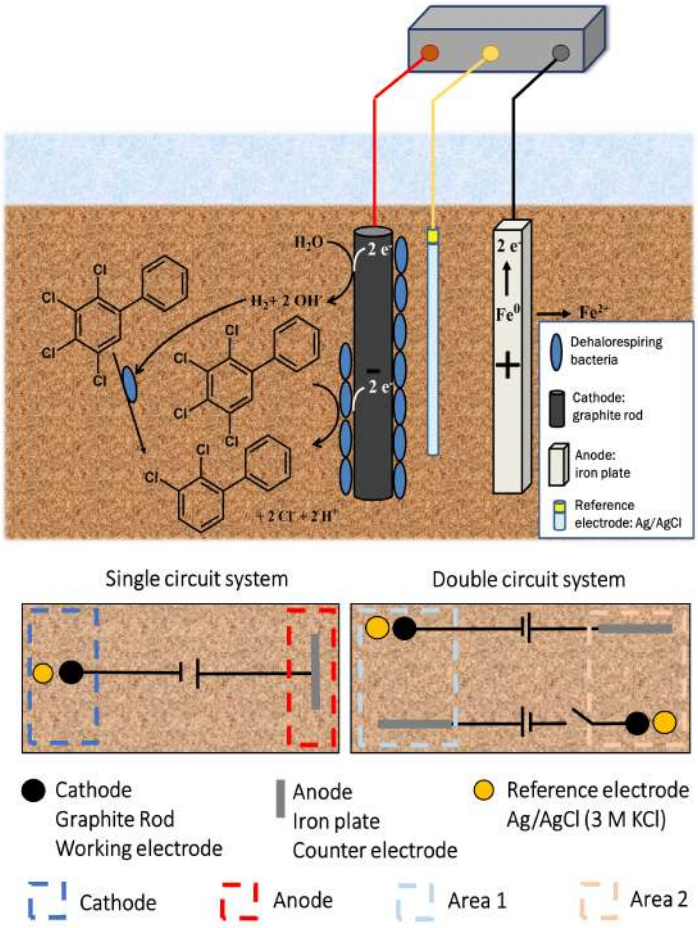
Using a single and a double circuit system. The double circuit aimed to mitigate the electrochemical impact on the sediment (e.g., pH), by alternately closing and opening the two circuits.

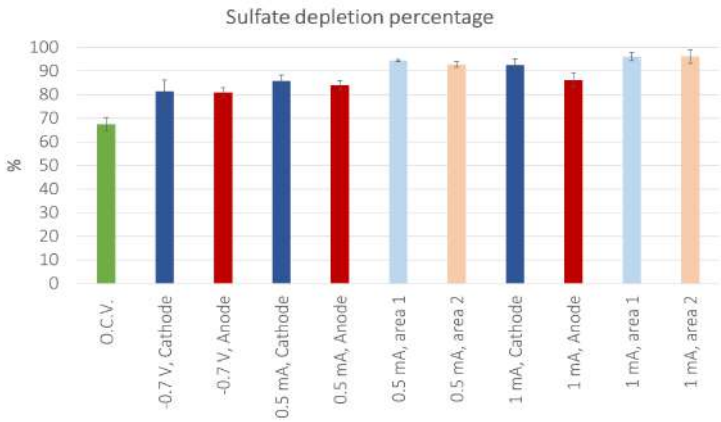
Studying several conditions: potentiostat posed at -0.7 V vs Ag/AgCl; constant current flow of 0.5 mA and 1 mA; no voltage applied (O.C.V.)

## Main results

Sulfate reduction was stimulated in all the bioelectrochemical set-up.

The reductive dehalogenation was inhibited by the bioelectrochemical stimulation.

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## *METland® technology: METfilter's innovative technology for wastewater treatment*

METland® technology arises from the combination of two technological concepts: one more classic and accepted, that of treatment wetLAND; and another more innovative one, that of microbial electrochemical technologies (MET, for its acronym in English). Treatment wetlands are based on the use of fixed bed biofilters that combine the use of microorganisms and plants to remove contaminants without external input of energy or generation of sludge.

These natural systems of undoubted sustainability and minimal carbon footprint are, however, subjected to the requirement of a high surface area per equivalent inhabitant (3-5 $m^2$/ PE). To convert a classic wetland into a METland® technology, we resort to a type of microorganism, called electroactive, capable of mineralizing contaminants and transferring the generated electrons to electrically conductive materials with which the biofilter bed is built. The result is a stimulation of microbial activity by minimizing the classic redox limitations in this type of system, that is, the availability of electron acceptors in the water, necessary for the efficient microbial oxidation of contaminants. The combination of these bacteria and an innovative material allows to treat about 25$m^3$ of wastewater from domestic use in just 12 $m^2$ of surface (approx. 0.1$m^2$/PE) by using a modular configuration of 20 feet.


### Different Solutions

The METland® modular system represents a sustainable (technical, economic, and environmental) mobile (fits in transport containers) and an efficient solution to clean and reuse urban wastewater with zero energy. METland® systems include the use of plants that turn a sewage treatment device into a garden landscape, while also housing innovative biotechnology. In addition, these systems reduce the area footprint by 30 times. It complies with Green Deal policies related to $CO_2$ footprint and energy consumption to help EU states achieve climate neutrality in the water sector.

*Figure 9: 1m³ modular type METland® designs, able to couple in several units with different configurations (down-flow, flooded or mixed).*

## Awards and Recognitions

- Best European Project XI madri+d Awards (2016) Madrid Regional Government, Spain
- Innovation Radar Smart & Sustainable Society Innovation (2020) European Commission
- Global Innovation Award (2020) Ministry of Environment and Climate Change, UAE
- Top 3 EU Biotech (2020), 300 proposals
- Innovation Award (2021) ISMET Society

METfilter

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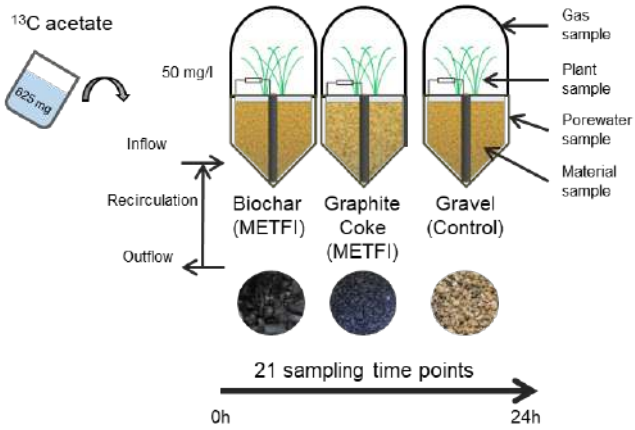
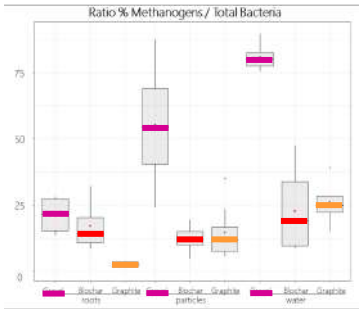
# Constructed Wetlands with conductive bed materials to optimize degradation performance

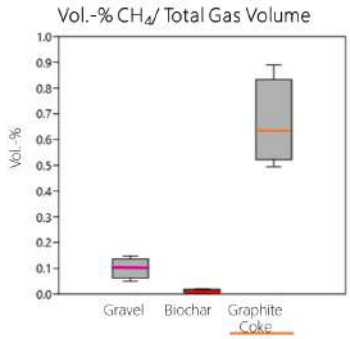
The main objective of this study was to show that conductive bed materials can optimize degradation performance of constructed wetlands and lower the presence of methanogenic bacteria.

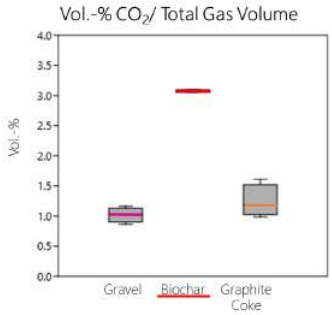
## Specific research outcomes

- DOC removal rates for all systems with recirculation is higher than without recirculation
- effect of recirculation is stronger than effects caused by materials
- electro-conductive filter beds perform better under high organic loads than gravel beds
- biochar can store electrons from the microbes
- If properly managed, conductive bed materials can reduce the methane concentrations of CW

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## Phytoremediation of Sb-contaminated soils

Phytoremediation of an antimony (Sb) contaminated soil was investigated with the aim to enhance its effectiveness by bioaugmentation and biostimulation.

*Tamarix smyrnesis* plants were exposed to a mixture of antimony (0; 50; 250 ppm), manganese (0 ;150 ppm) and sodium chloride (0; 0.3 %). The effect of selected plant rhizobacteria was assessed. A metal-resistant, root endophytic community was isolated and used for bioaugmentation.

*Tamarix smyrnesis plants bioaugmented with a root endophytic community*

**Bioaugmentation** had a significant effect on the uptake of Sb in the roots and in the leaves of *Tamarix smyrnesis* when the initial soil concentration was high (250 ppm). The presence of Mn was found to enhanced the bioavailable fraction of Sb.

The **biostimulant** potential of three different organic acids (citric, oxalic and ascorbic acid) supplemented in the rhizosphere was investigated. The addition of low (70mM) and high concentration (0.7 M) organic acids was employed. The addition of the biostimulants in low and high concentration took place every 14 and 25 days in the plants, respectively.

The addition of the highest concentration of organic acids resulted in the greatest uptake of Sb , Fe and Mn from the soil and translocated to the root and the leaves.

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## *Effect of oxygen supply in Constructed Wetlands for treating petroleum hydrocarbons*

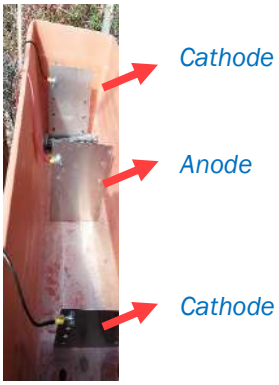
Aerated constructed wetlands (CWs) demonstrate superior performance compared with non-aerated systems. Forced aeration of horizontal subsurface flow constructed wetland is a recognized method to improve treatment efficiency. Three CWs were tested (CW1: Control unit, CW2: Nanobubbles aeration unit, and CW3: electrochemical oxygenation unit).


CW2:

Polyethylene (PE) nano-tube bubble diffuser has been employed for aeration of CW2. The diffuser has aeration pore diameter ranging from 0.3 μm to 100 μm.

CW3:

The anode was set in the middle of the unit, and the cathode consisted of two iron plates, which were set on both sides of the anode. Both electrodes were iron plates of 250 mm, long, 175 mm wide and 0.2 mm thick. The surface area ratio of the cathode to anode used in this study was 2:1 The iron plates contained many pores with a diameter of 10 mm and distance of 20 mm apart to let water pass through easily.




### Outcomes

- Constructed wetland with ultra-fine bubbles exhibited the **best performance.**
- Dissolved oxygen in CW2 remained > 7 mg/L in every cycle
- The addition of municipal wastewater enhanced the removal rate in CW3.

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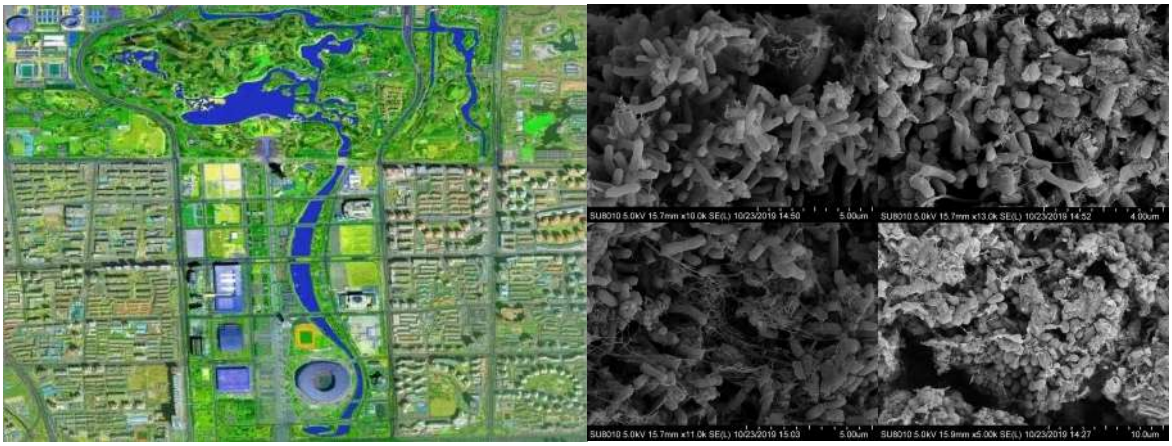
## *Enrichment workflow – isolation of degraders*

1）Sludge samples collected from dragon shaped water system in Beijing.

2）Samples were inoculated into MSM with antibiotics ranged from 5 to 30 mg /L once every two weeks under anaerobic and aerobic conditions.

3）Isolation was carried out by the serial dilution on MSM agar， R2A agar and LB agar containing antibiotics. Bacterial isolates were identified by 16S rRNA gene sequence analysis.

4）The degradation efficiency of each sample was determined by high-performance liquid chromatography (HPLC).



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## TBBPA-degradation assay

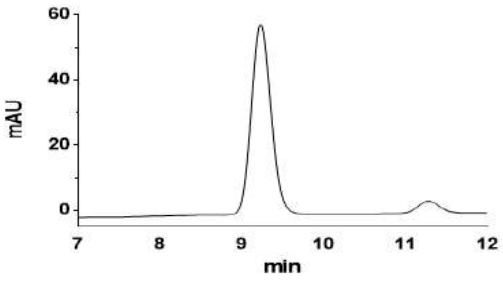
The developed protocol is as follows:

- Add 1%(v/v) of 2M NaOH to totally resolve TBBPA
- Column: Agilent Eclipse XDB-C18 (4.6 x 250mm, 5µm)
- Mobile phase: 0.1% (v/v) formic acid in ultrapure water as solvent A and methanol as solvent B
- Flow rate: 1mL/min
- Wavelength: 220nm (TBBPA), 278nm (BPA)

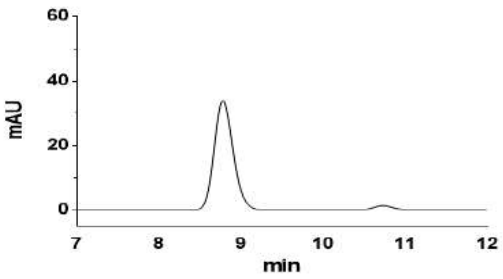
Typical results where the degradation is shown by the decrease in the peak area

0 d

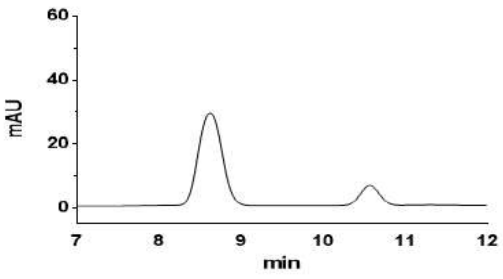
10mg/L TBBPA




7 d




10 d

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# Scientific output

ELECTRA has disseminated its scientific achievements in a number of publications and conference presentations. For the complete list, refer to our website.

**2019**


1. Yi-Xuan Wang, Wen-Qiang Li, Wen-Ming Zong, Tian-Yu Su, Yang Mu* (2019) Polyaniline-decorated honeycomb-like structured macroporous carbon composite as an anode modifier for enhanced bioelectricity generation. **Science of The Total Environment**. 696, DOI.
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12. Yangcheng Ding, Wenli Jiang, Bin Liang, Jinglong Han, Haoyi Cheng, Muhammad Rizwan Haider, Hongcheng Wang, Wenzong Liu, Shuangjiang Liu, Aijie Wang. (2020) UV photolysis as an efficient pretreatment method for the decomposition of antibiotics and elimination of antibacterial activity. **Journal of Hazardous Materials**, 392: 122321, DOI.
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## Keynote and Plenary Conference Presentations

ELECTRA partners have been invited to and participated in several international conferences and gave a number of keynote and plenary lectures:

1. **KEYNOTE:** Puig, S. "Niches for Electro bioremediation of contaminated waters". International society for microbial electrochemistry and technology: International Meeting (ISMET 7). 7-10 Oct 2019. Okinawa, Japan.
2. **KEYNOTE:** Korneel Rabaey, "Scaled up, high rate production and extraction of volatile fatty acids from CO2 and electricity", International society for microbial electrochemistry and technology: International Meeting (ISMET 7). 7-10 October 2019. Okinawa, Japan
3. **KEYNOTE:** Abraham Esteve-Núñez. "METlands for wastewater treatment". Northwest China Water Environment Young Scholars Forum. Xi'an (China) 25 May 2019.
4. **KEYNOTE:** Philippe Corvini, "Bacteria feeding on antibiotics – eating the poisonous". 2nd International Meeting on New Strategies in Bioremediation Processes- BIOREMID 2019, Porto, Portugal (24-25 Nov 2019).
5. **KEYNOTE:** Federico Aulenta (2019) "Novel electrobioremediation strategies for cleaning up sediments contaminated by petroleum hydrocarbons". 2nd International Meeting on New Strategies in Bioremediation Processes- BIOREMID 2019, Porto, Portugal (24-25 Nov 2019).
6. **KEYNOTE:** Philippe Corvini, "Bacteria feeding on antibiotics – eating the poisonous". ISPTS-2019, Stevens Institute of Technology, Hoboken, NJ (Oct 25-28, 2019)
7. **PLENARY:** Jiandong Jiang. The IUPAC2019 GHENT (Crop Protection Chemistry), Advances in pesticides biodegradation and metabolism: Mechanisms, applications and regulatory issues. 19-24 May 2019, Ghent Belgium. Microbial catabolism of chemical pesticides: the mechanism and its potential application.
8. **KEYNOTE:** Puig, S. Niches for Electro bioremediation of contaminated waters. Conference 7th International Society of Microbial Electrochemistry and Technology conference (ISMET7-2019). 7th-11th October 2019 in Okinawa (Japan).
9. **KEYNOTE:** Puig, S. Electro bioremediation of contaminated waters. Conference Technology Innovation for Sustainable Water. 3th-6th September 2019 in Daegu (Korea).
10. **PLENARY:** Nicolas Kalogerakis "Ecosystem and Engineering process applications of air nanobubbles", 5th International Conference on Chemical Engineering (ICCE-2020), 28-30 October 2020, Iasi (Romania).
11. **INVITED:** Esteve-Núñez, A. *Metland, from fundamental bioelectrochemistry to the real world*. SPP2440 e-Biotech Summer School 2022. Technical University Hamburg. Hamburg, Germany. 1/09/2022
12. **KEYNOTE:** Esteve Núñez, Abraham. *Bioelectrochemical Systems Scale-Up from nm to m³*. MEEP 2022 - Special Symposium on Microbial, Enzymatic & Bio-Photovoltaic Electrochemical Reactors, Fuel Cells and Electrolyser Systems. Lucerne, Switzerland (06/07/2022 - 07/07/2022).
13. **PLENARY:** Esteve Núñez, Abraham. Electrobioremediation, a new player in the water sector: case studies. 8th European Bioremediation Conference -EBCVIII. Chania, Crete, Greece. (12/06/2022 - 17/06/2022).
14. **KEYNOTE:** Esteve-Núñez, A. H2020 ELECTRA. Electricity driven Low Energy and Chemical input Technology foR Accelerated bioremediation. Life Clean Up – Networking Days. Online. 1/06/2022
15. **KEYNOTE:** Esteve Núñez, Abraham. *Microbial Electrochemical Technologies (MET) already grew up to play a promising role in the water sector: case studies.* XXVII International symposium on Bioelectrochemistry and Bioenergetics. Antwerpen, Belgium. (03/04/2022 - 07/04/2022).
16. **KEYNOTE:** Rong Ji, Formation and stability of non-extractable residues (NER) of emerging organic pollutants in soil, The 11th National Conference on Environmental Chemistry, Harbin, July 25-29, 2022

# Consortium

### European partners funded by H2020

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Technical University of Crete (Greece)

Universitat de Girona-LEQUIA (Spain)

Universiteit Gent - CMET (Belgium)

University of Rome La Sapienza (Italy)

National Research Council - Water Research Institute (Italy)

Helmholtz-Centre for Environmental Research (Germany)

IEG Technologie GmbH (Germany)

Budapest University of Technology and Economics (Hungary)

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