Climate change, population growth and depletion of natural resources are among the greatest challenges for the near future. Water, as a life-essential natural resource undergoes significant anthropogenic pressure due to elevated generation of wastewater loaded with nutrients and wide range of the problematic micropollutants. Effective wastewater treatment is the priority of water resources protection. This goal should be accomplished with use of technologies characterized by low environmental footprint, which is in line with the circular economy paradigm and Sustainable Development Goals proposed by United Nations. Floating Treatment Wetlands (FTWs) fulfill these assumptions as they are based upon purification processes naturally occurring in the environment; they are also characterized by low energy demand and low emission. FTWs are floating rafts planted with hydroponically growing macrophytes. The roots expand in the water column and form a dense mat colonized by microorganisms. Transformation of pollutants in FTWs is a result of a variety of processes, in which the biotic system components: macrophytes and microorganisms and the synergistic interactions between them play the key roles.

In this project the research activities will be focused on integration of FTWs with Microbial Fuel Cells (MFC), which is a novel concept in wastewater purification allowing for improving remediation effects and for recovery of bioelectricity at the same time. It has been recognized that MFC is able to use wastewater as a substrate and remove a variety of contaminants in the process, also showing promising results for the removal of micropollutants. Introduction of the electrodes (anode and cathode) into FTW encourages development of electrochemically active microorganisms (EAB), which are considered to be the major factor leading to fluctuation of bioelectricity and changes of the microbial community structure. The research hypothesis assumes that FTW-MFC integration will boost transformation and removal of selected micropollutants: pharmaceuticals (azithromycin, remdesivir and acetaminophen), heavy metals (chromium and cadmium) as well as arsenic. Micropollutants pose a major threat to ecosystems and humans, thus searching for effective and at the same time sustainable methods of their removal from wastewater is a key issue to be addressed by researchers.

The objective of the project is to investigate the mechanisms underpinning bioenergy generation and transformation of selected micropollutants in FTW reactors integrated with MFC (FTW-MFC). A novel "**3M**" research approach, which integrates analyses of **m**acrophytes, **m**icrobiomes (specialized microbial communities) and mathematical **m**odelling of the processes of transformations of nutrients and selected micropollutants in FTW-MFC is proposed. The experiments will be performed in mesoscale FTW-MFC and conventional FTW reactors (control) continuously fed with synthetic wastewater. The analyzed experimental systems will differ in terms of 1) species of applied macrophytes (*Phragmites australis* vs *Iris pseudacorus* vs a mix of both) 2) technological parameters (hydraulic retention time HRT, organic loading rate OLR), 3) environmental conditions (natural vs artificial controlled lightening), 4) influence of various micropollutants occurrence in feeding wastewater (selected pharmaceuticals, heavy metals and arsenic). Plant and bacterial activity will be assessed for nutrient removal efficiency and processes rates estimations between conventional FTW and MFC-FTW systems, under specific operational conditions, to evaluate the contribution of the MFC implementation to the system performance. Morphological and anatomical response of macrophytes to abiotic stress caused by micropollutants and electric field will be studied. The same set of environmental and stressors will be validated in relation to the diversity and structure of microbial communities creating various bio-components (rhizosphere, MFC biofilm, and suspended biomass) in the FTW-MFC reactor. Extensive analyses of FTW-MFC bio-components will be supported by multidimensional data analysis, uncertainty analysis (GLUE) and global sensitivity analysis (GSA) followed by building, calibrating and validating mechanistic models for simulation of bioenergy and pollutant removal efficiency in FTW-MFC system.

The holistic approach applied in the project will make a significant step towards understanding the processes and factors underpinning bioenergy production and micropollutants transformations in FTW-MFC systems in relation to the interkingdom interactions between plants and microbiome. Additionally, proposed project will contribute to the advance in innovative and sustainable wastewater purification in FTW-MFC allowing for simultaneous bioenergy recovery, which is in line with the circular economy paradigm and Sustainable Development Goals.