ULTRABUBBLES

Nanobubble technology for sustainable wastewater treatments: micro-algae recovery and simultaneous micro-pollutant and microplastics removal

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Abstract

The concentration of Micro- and Nano-Plastic particles (MNPs) and Micro-Pollutants (MPs), such as antibiotics and cosmetics, in urban and industrial wastewaters is substantially high, and the inefficiency of traditional wastewater treatment processes poses a significant risk of their discharge into natural environments. Once wastewaters reach the oceans, the possibility of successfully detecting and removing these undesired elements drastically decreases. Currently, suspended MNPs and MPs are detected in all treated waters in the EU, with some posing hazards to public health and the environment even at very low concentrations. Therefore, MNPs and MPs must be removed by upgrading wastewater treatment plants with new technologies. Advanced treatment techniques must be developed to meet the European "zero pollution action plan" target for 2045. These techniques should be sustainable, preferably avoiding the use of chemical additives, and applicable to both large and small urban communities.

ULTRABUBBLES is a basic-research project aimed at developing and demonstrating the efficiency of an innovative advanced wastewater treatment technology, hereinafter referred to as ULTRABUBBLES technology. This technology aims to remove MNPs and MPs by combining flotation, adsorption, and oxidation of emerging contaminants using NanoBubbles (NBs) and MicroAlgae (MAe), which are harvested, reused, and ultimately separated from the effluent.

Two processes will be explored.

The first integrates multiple treatment mechanisms within a single reactor system. This approach combines aggregation of dispersed microplastic particles, NB-enhanced flotation for their separation, and advanced oxidation processes for the degradation of recalcitrant pollutants, offering both environmental and economic benefits, with removal efficiencies exceeding 96%.

MAe have shown remarkable ability to adsorb MNPs from wastewater, forming the basis of the second process. This approach relies on the bioadsorption of MNPs by suspended microalgal biomass, followed by NB flotation as a sustainable alternative to conventional MAe recovery methods, thereby reducing the typically high operational costs. The project will also investigate the use of CO2 NBs - potentially extracted from activated sludge and biological filters in the secondary treatment stage - to provide MAe with a carbon source. This CO2 supply would enhance the diurnal photosynthesis of green algae while simultaneously contributing to CO2 reuse and valorisation (carbon sink). A final treatment with ozone NBs will inactivate residual MAe before the effluent is discharged into the natural environment.

ULTRABUBBLES technology will contribute to shift wastewater treatment plants from a linear "treat and discharge" model to a circular "capture–reuse–restore" loop. In fact, secondary waste generation is minimised by relying on clean physical–biological mechanisms, MAe enriched with microplastics and other adsorbed contaminants are recovered, while CO2 from wastewater treatment residues is reused turning a greenhouse gas into a productive input.

To enable the development of the ULTRABUBBLES technology, a model describing the physical and chemical processes responsible for the aggregation of MNPs and MAe, as well as the oxidation of MPs, will be developed and validated against a unique series of multi-scale laboratory and numerical experiments. The high removal efficiency will be supported by innovative hybrid NB generators developed by Nanobubbles Europe, a rapidly growing European leader in NB technologies. The scalability of the ULTRABUBBLES technology will be assessed using a pilot-scale prototype reactor and tested according to the requirements of the project stakeholders.

Project coordinator

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Project partners

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- UNIVERSITY OF UDINE - ITALY
- NANOBUBBLES EUROPE LLC - HUNGARY

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