Recent advances in biotechnologies for a cost-effective abatement and valorization of greenhouse gases: moving towards GHG biorefineries

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CH_4 and N_2O emissions represent 20 % of the anthropogenic greenhouse gas (GHG) emissions, and their share is expected to increase in this 21st century based on the steady increase in human population. Based on the recent COP 21 Paris agreement to limit the increase in global average temperatures to 2 ºC above pre-industrial levels, the European Union has committed to reducing its GHG emissions by 40% by 2030 and 60% by 2040 (compared to 1990 levels). Apart from the current actions oriented to reduce CO_2 emissions from fossil fuel combustion, additional measurements such as an active CH_4 and N_2O abatement must be considered in order to achieve these target emission cuts. Despite the increasing environmental relevance of CH_4 and N_2O, minimum attention has been paid to date to these greenhouse gas emissions from a legislation and abatement viewpoint worldwide. This has limited the development of cost-efficient and environmentally friendly end-of-pipe treatment technologies. Physical/chemical treatment methods for CH_4 abatement such as incineration, and for pre-concentration like activated carbon adsorption, are either inefficient or costly at the low concentrations (1-5%) typically found in emissions from waste treatment activities, coal mining or animal farming. On the other hand, conventional NO_x treatment technologies such as selective catalytic reduction, selective non-catalytic reduction, adsorption or scrubbing present prohibitive operating costs (and large environmental impacts) when treating large volumes of air containing low concentrations of NO_x (as a result of their intensive use of energy and chemical). In this context, biotechnologies could become, if properly tailored, a low-cost and environmentally friendly treatment alternative to physical/chemical methods for the abatement of CH_4 and N_2O emissions. Biotechnologies, which are based on the biocatalytic action of specialized microorganisms, have been consistently proven as robust and efficient methods for the treatment of industrial volatile organic compounds (VOCs) and malodours, exhibiting lower operating costs and environmental impacts than their physical/chemical counterparts. These biological technologies are based on the biodegradation of these GHG pollutants by specific microbial communities, which transform them into less harmful products such as CO_2, N_2 or H_2O. Unfortunately, conventional bioreactors such as biofilters, biotrickling filters or bioscrubbers are limited by the mass transfer of these GHGs from the gas to the liquid phase as a result of their high henry law constant. Under optimal operating conditions, GHG-laden emissions can be also used by microorganisms as raw materials to synthesize high added value products such as biopolymers, exopolysaccharides, vitamins or ectoine. The valorization of these waste gases through their bioconversion into commodities with a high market value will turn their abatement into a sustainable and profitable process. This keynote will critically review the recent advances in high-mass transfer bioreactors applied to CH_4 and N_2O removal, and the potential biological valorization of these GHGs as added value products.