UNIVERSITÀ DEGLI STUDI DI SALERNO

Dipartimento di Ingegneria Civile

Tesi di Dottorato
in
Rischio e sostenibilità
nei sistemi dell'ingegneria civile, edile ed ambientale

XXXI (2015-2018)

ADVANCED SOLUTIONS FOR THE ABATEMENT OF VOCs AND ODOURS

Abstract

Giuseppina Oliva

Tutor
prof. ing. Vincenzo Naddeo

Coordinatore
prof. ing. Fernando Fraternali

Co-Tutor
prof. ing. Vicenzo Belgiorno

Abstract

In the last decades, atmospheric pollution has become an increasingly alarming problem, due to its adverse effects at the global, regional and local scales.
In this context, the emissions of Greenhouse Gases (GHGs), Volatile Organic Compounds (VOCs) and odours from chemical manufacturing plants, petrochemical sector and other hazardous sources pose a major challenge.
Global warming, due to increased GHGs level in the atmosphere, has been identified as one of the key challenges in this century. Indeed, the impacts of global warming have caused severe damages towards human and environment ecosystem.
VOCs are included among the priority gaseous organic contaminants, with BTEX identified among the most dangerous for human health. They are also considered responsible for the photochemical pollution as a result of their reaction in the atmosphere with nitrogen oxides in presence of solar radiation. In addition, their tendency to volatilize readily to the atmosphere leads to problems connected to odour annoyance.
These aspects triggered the enforcement of stricter regulations and, consequently, boosted the necessity of properly manage atmospheric emissions.
The conventional chemical-physical processes mainly used for the treatment of these kinds of emissions envisage the contaminants transfer to other phases and, thus, the necessity of further treatments. Biological processes and Advanced Oxidation Processes (AOPs), instead, are able to support the degradation and mineralization of organic compounds, resulting in more effective solutions. Furthermore, AOPs applied as pretreatments at biological processes may improve VOCs biotreatability and control the accumulation of biomass.
Moreover, since the biological treatment of high concentrations of VOCs might cause a limitation of the oxygen available for the aerobic degradation due to the reduced water-solubility of this compound, the synergic activity of microalgae and bacteria represents an efficient alternative to support the simultaneous abatement of CO_2 and VOCs. In algal-bacterial photo-bioreactors, microalgae produce oxygen during the photosynthetic process in the presence of light and CO_2, while heterotrophic bacteria utilize the additional O_2 supply to accelerate the oxidation of organic compounds. In turn, the CO_2 resulting from the mineralization process is

fixed by the microalgae. Mechanisms underlying microalgae activity might not only prevent oxygen limitation but also enhance the biodegradability of the target VOC. In this context is framed the research activity discussed in the present work, aimed to:

- the comparative evaluation of UV-assisted ozonation and its combination with conventional processes in different operating conditions;
- the comparative evaluation of two different biological reactors and the assessment of their continuous toluene degradation performances under different operating conditions;
- the scale-up of the proposed systems and the assessment of the technical feasibility.

To this end, experimental activity was structured in two main steps:

- the first one was focused on the assessment of ozone and photolysis effectiveness in promoting toluene degradation;
- the second part was focused on the assessment of enhanced biological processes for the continuous removal of gaseous toluene.

The first part of the research, focused on the comparative assessment of different configuration of AOPs systems, was performed at the Sanitary Environmental Engineering division (SEED) of Salerno University. Toluene was identified as target compound for the experimental activities. A lab-scale UV/O_3 reactor was investigated for the degradation of VOCs emissions under different operating conditions, in order to highlight the influence of the inlet concentrations and the ozone dosages. A novel configuration with an additional scrubbing phase is proposed and assessed to improve the removal efficiency and to prevent the release of polluting intermediates of the single-step process. The combined system boosted higher performance and stability compared to the stand-alone (UV/O_3) process along with a more economical and environmental sustainability.
In the second phase, the experimental activity was performed at the Department of Chemical Engineering and Environmental Technology of Valladolid University. The experimental activity aimed at evaluating and systematically comparing the continuous toluene degradation performance of the proposed biological reactors, a conventional bacterial Biotrickilng Filter (BTF) and an innovative Tubular Photo-BioReactor (TPBR). Different operating conditions have been investigated, varying the Empty Bed Residence Time (EBRT) and the toluene inlet concentration to gradually increase the Inlet Load (IL) entering the systems. Toluene mass transfer tests have been carried out in order to determine the limiting stage, and a final

robustness test performed to assess the capacity of the systems to face inlet load fluctuations.

The results obtained demonstrated the potential of the synergic effects between bacteria and microalgae. The higher DO concentrations ensured oxygen availability for the microbial community and improved the process performances. The carbon dioxide released from mineralization process was utilized for the valuable biomass production.

Conventional processes with AOPs pretreatment and microalgae-bacteria consortium inoculation thus represent innovative and promising methods for the increase of treatment efficiencies, biomass valorization and GHGs reduction.

The combination of conventional and advanced processes represents a sustainable platform to reduce the emission of undesirable byproducts, besides treating high concentrations of VOC.