Bio-scrubber coupled with ozonation for enhanced VOCs abatement

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Abstract

Volatile Organic Compounds (VOCs) are toxic for the environment and human health and their tendency to readily volatilize in the atmosphere leads to problems connected to odours annoyance. The conventional treatments for VOCs gaseous emissions conventionally entail the application of chemical-physical processes, only promoting the transfer of the contaminants from gas to liquid and/or solid phases. Advanced Oxidation Process (AOPs) and biological processes, conversely, support the oxidation of the organic pollutants, promoting their conversion into harmless and odourless compounds.

This study aims at evaluating the performance of an innovative treatment solution, at pilot scale, of AOPs pretreatment coupled with a bio-scrubbing unit for the abatement of toluene, selected as model VOCs. Different operating conditions have been evaluated to understand the behavior towards inlet load fluctuations.

The results exhibited that the ozonation applied as pretreatment to the biological process may promote an increase of the pollutant biodegradability along with synergic effects due to the absorption of the ozone derived compounds into the culture growth, resulting in a significant enhancement of removal performances respect to the conventional biotechnologies.

Keywords: Biomass; Bio-Scrubbing; Ozonation; Toluene.

1. Introduction

Volatile organic compounds (VOCs) emitted from chemical manufacturing plants, petrochemical industry and other industrial sources can cause problem to human and environmental health (Berenjian et al. 2012). For these reason, over the past years it has been triggered the development of convenient and environmentally friendly abatement technologies (Kumar et al., 2019). VOCs can be removed from contaminated wastegas streams by physical, chemical or biological processes. Biological treatment technology for VOCs removal have gained popularity thanks to the several advantages they offer in comparison to conventional physical and chemical removal methods (Muñoz et al. 2012). Biotechnologies are considered significantly suitable for the treatment of diluted emissions, at relatively high gas flow rates. For overcoming conventional wastegas treatment technologies drawbacks, it has been investigated the application of AOPs in a novel wastegas treatment configuration, entailing ozonation applied as pretreatment to a conventional bio-scrubber. The results are discussed to highlight the increased removal yields and the control of the biomass accumulation supported by the combination of the advanced oxidation with the biological process (Oliva et al., 2018). It has been thus demonstrated that the combination of biotechnologies and AOPs resulted in synergy effect for the enhancement in toluene removal.

2. Materials and Methods

The experimental setup consisted of a vertical absorption column (VAC) and a mixing chamber for the recirculation of the liquid phase (Fig. 1). The VAC consists a PVC cylinder of 130 cm of height and 6 cm of inner diameter with a working volume of 3.3 L. The volume of mixing chamber was around 18 L. The contaminated air stream was obtained injecting toluene by using a syringe pump (NO300, New Era Pump System) in the compressed air line. The contaminated stream was mixed with ozone-enriched stream in a gas mixing chamber. The mixed stream was supplied to the bio-scrubber from the bottom of the column by a metallic diffuser (Knauer Mobile Phase Filter, SS, 2μm, 1/8" pipe OD). The bioreactor was inoculated with activated sludge from the municipal wastewater treatment plant located in Salerno (Campania Region, Italy). The inoculum was prepared using 0.5 L of activated sludge, centrifuged for 10 minutes at 6000 rpm and resuspended in 250 mL of Mineral Salt Medium (MSM). The initial pH value and TSS of inoculum was around 7.0 and 7 g L^{-1}, respectively. The MSM was composed of (g L^{-1}): Na_2HPO_4 (2.44); KH_2PO_4 (1.52); NH_4SO_4 (1.00); $MgSO_4 \cdot 7H_2O$ (0.20) and $CaCl_2 \cdot 2H_2O$ (0.08) and 10 mL L^{-1} of SL-4 stock solution containing: EDTA (0.50 g L^{-1}) and $FeSO_4 \cdot 7H_2O$ (0.20 g L^{-1}) and 100 mL L^{-1} of SL-6 stock solution composed of (g L^{-1}) $ZnSO_4 \cdot 7H_2O$ (0.10); $MnCl_2 \cdot 4H_2O$ (0.03); H_3BO_3 (0.30); $CoCl_2$ (0.20); $CuCl_2 \cdot 2H_2O$ (0.01); $NiCl_2 \cdot 6H_2O$ (0.02); $Na_2MoO_4 \cdot 2H_2O$ (0.03). Toluene of 99.9 % produced by Sigma-Aldrich Corporation (Darmstadt, Germany) was employed in this work. Inlet and outlet toluene concentrations were daily measured by a GC-PID (Tiger, Ion Science). Liquid samples were daily drawn out to measure pH, temperature, DO, total organic carbon (TOC) and total suspended solid (TSS).

Different operating conditions have been investigated. The bio-scrubber was operated continuously for 60 days at inlet toluene concentrations gradually increased from 150 to 600 mg m^{-3}, gas flow rates from 2.5 L min^{-1} to 5 L min^{-1} and the toluene inlet load were varied from 4.5 g m^{-3} h^{-1} to 27. The ozone loading rate was increased from 500 to 920 g m^{-3} h^{-1}.The performance parameters of the bio-scrubber were evaluated in terms of the inlet load (IL, g m^{-3} h^{-1}), elimination capacity (EC, g m^{-3} h^{-1}) and removal efficiency (RE, %).

3. Results

A bio-scrubber coupled with ozonation was successfully investigate under different toluene loading rates. During steady-state operation, for IL up to 10.6 ± 1.9 g m^{-3} h^{-1} a 78 ± 2 % removal of toluene was achieved without ozonation. At the ozone loading rate of 920 g m^{-3} h^{-1} was obtained an average removal efficiency of 98 %, corresponding to an EC of 13.81 ± 2.0 g m^{-3} h^{-1}.

4. Conclusion

Good results have been obtained thanks to the synergistic effects between the two combined processes, emphasizing that ozone pretreatment may promote not only the increase in pollutants biodegradability, preventing inhibiting conditions for the activity of microorganisms even at high concentration of toluene, but also the accumulation of excess biomass.

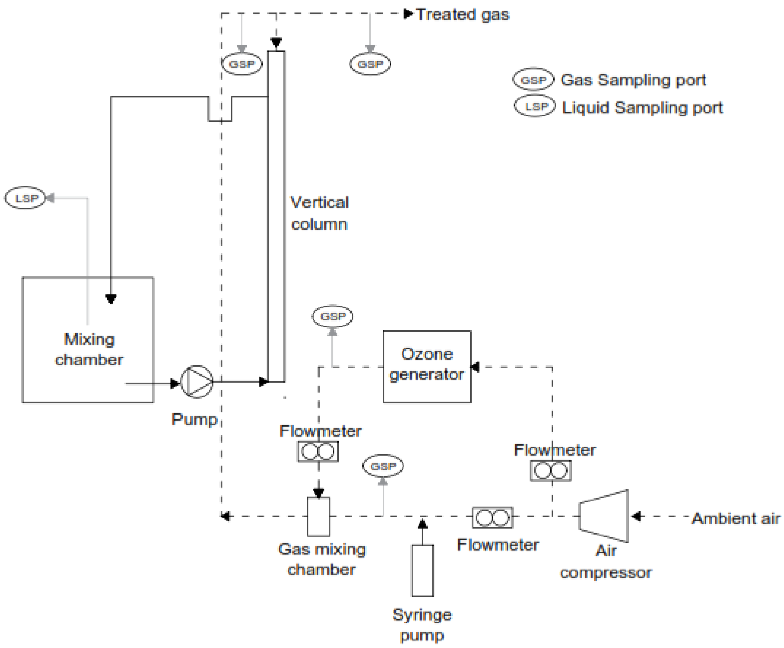

Figure 1. Experimental set-up

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