

Benefits and technological challenges in the implementation of TiO₂-based ultraviolet photocatalytic oxidation (UVPCO) air cleaners

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Introduction

Indoor air cleaners based on TiO₂ photocatalytic oxidation of organic pollutants are a promising technology to improve or maintain indoor air quality while reducing ventilation energy costs. We evaluated the performance of a pilot scale UVPCO air cleaner under realistic conditions in single pass and recirculation modes.

Materials and Methods

The photocatalyst (Degussa P25 impregnated with 3% tungsten oxide) was applied as a thin coating layer on the surface of two 30 x 30 cm honeycomb monoliths, which were illuminated with 12 UVC lamps. The system was operated at 740 – 780 m³/h in single-pass experiments. Individual common indoor VOCs and mixtures of these compounds were infused into a duct upstream of the device. Replicate air samples for VOCs and aldehydes were collected upstream and downstream of the reactor and analyzed by thermal desorption-GC/MS and HPLC. Single-pass conversion efficiencies of individual VOCs were evaluated, and formation yields of the partial oxidation products, formaldehyde and acetaldehyde, were determined. Experiments also were conducted in a 50-m³ chamber provided with a constant source of these same VOCs. The outdoor air supply was 169 m³/h and chamber air was recirculated through the device at 685 m³/h. Air samples were collected initially and hourly for 6 h after turning on the lamps.

Results

The data presented in Table 1 correspond to VOC removal efficiency determined for the infusion of each individual analyte as well as for the mixture of the studied compounds, at inlet

concentrations in the range 12 – 150 ppbv. Formaldehyde was generated as a partial oxidation byproduct, principally due to incomplete oxidation of d-limonene (41% yield), 2-butoxyethanol (25%) and methyl isobutyl ketone (22%). Significant production of acetaldehyde was observed for the reaction of ethanol (10% yield), 2-butanone (8%), 1-butanol (7%) and hexanal (5%). Recirculation results were consistent with single-pass experiments.

Table 1. VOC removal efficiency for individual analyte vs. mixture infusion.

Compound	Individual	In mixture
Methanol	0.28 ± 0.04	0.29 ± 0.07
Ethanol	0.51 ± 0.07	0.30 ± 0.05
Isopropanol	0.49 ± 0.11	0.35 ± 0.04
1-Butanol	0.40 ± 0.05	0.31 ± 0.03
2-Butoxyethanol	0.40 ± 0.06	0.41 ± 0.02
2-Butanone	0.30 ± 0.10	0.21 ± 0.07
MIBK	0.31 ± 0.07	0.31 ± 0.03
Hexanal	0.43 ± 0.02	0.38 ± 0.03
d-Limonene	0.31 ± 0.03	0.33 ± 0.03
Toluene	0.19 ± 0.03	0.17 ± 0.02

Discussion

VOC removal was efficiently achieved across a diverse set of chemical functionalities in single-pass configuration, with formation of undesired oxidation byproducts. Individual conversion efficiencies of eleven common VOCs were nearly identical to efficiencies determined for a mixture containing the same VOCs for all but two compounds. These results suggest that competition among compounds for active sites on the photocatalyst surface likely will not limit performance of the UVPCO device in most indoor air applications.