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PHOTOCATALYTIC REACTOR SYSTEM WITH TUNGSTEN OXIDE-MODIFIED TITANIUM DIOXIDE FOR INDOOR AIR APPLICATIONS

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An experimental evaluation of an ultraviolet photocatalytic oxidation (UVPCO) device with tungsten oxide-modified titanium dioxide as the photocatalyst is reported. This was a scaled device developed to demonstrate air purification when installed in a HVAC system of a commercial building. There were two 30 by 30-cm honeycomb monoliths and 12 18-Watt UVC lamps arranged in three banks. The evaluation employed several mixtures of volatile organic compounds (VOCs). One mixture contained 27 VOCs frequently identified as air pollutants in office buildings. Another mixture comprised 10 VOCs emitted by household cleaning products. A third mixture contained just formaldehyde and acetaldehyde. The concentrations of the mixtures and the air flow rate through the UVPCO were manipulated as variables. Summed mixing ratios of VOCs ranged from 54 to 780 ppb, with the mixing ratios of many individual VOCs maintained below 10 ppb. Device air flow rates were 165 to 580 m^3/h. Replicated air samples for the analysis of VOCs, low molecular weight carbonyls, and carboxylic acids were collected simultaneously both upstream and downstream of the reactor section. These were analyzed by thermal desorption GC/MS, HPLC and ion chromatography, respectively. Single-pass conversion efficiencies and clean air delivery rates were calculated for each VOC in inlet air. The generation of products of incomplete oxidation (carbonyls and acids) was quantified.

VOC conversion efficiencies varied over a broad range, usually exceeded 20%, and were as high as ~80%. Conversion efficiencies generally diminished in direct proportion with increased air flow rate, and were less affected by differences in inlet VOC concentrations. Conversion efficiency followed the approximate order: alcohols and glycol ethers > aldehydes, ketones, and terpene hydrocarbons > aromatic and alkane hydrocarbons > halogenated aliphatic hydrocarbons. Experiments with the office building mixture resulted in the net production of formaldehyde, acetaldehyde, formic acid and acetic acid indicating incomplete decomposition of some VOCs. Formaldehyde, acetaldehyde and acetone were produced in the cleaning product experiments. The overall aldehyde production rates were higher than aldehyde consumption rates in aldehyde-only experiments. Net production of formaldehyde and acetaldehyde suggests there is a potential for concentrations of these hazardous chemicals to increase with time in a building utilizing UVPCO to treat the supply air stream (i.e., outdoor air plus recirculated indoor air).

Conversion efficiencies were observed to correlate with the Henry's law constant of the studied VOCs more closely than with other physicochemical parameters. An empirical model based on the Henry's law constant and including the gas-phase reaction rate with hydroxyl radical facilitated an estimate of pseudo-first order photocatalytic reaction rates for the studied VOCs. Good agreement was achieved between modeled and experimental values for a wide range of VOCs spanning nine orders of magnitude of Henry's law constant values.