

RT-MATRIX: Measuring Total Organic Carbon by Photocatalytic Oxidation of Volatile Organic Compounds



Elemental and
Gas Composition
Sensors

Volatile organic compounds (VOCs) inevitably accumulate in enclosed habitats such as the International Space Station and the Crew Exploration Vehicle (CEV) as a result of human metabolism, material off-gassing, and leaking equipment. Some VOCs can negatively affect the quality of the crew's life, health, and performance; and consequently, the success of the mission. Air quality must be closely monitored to ensure a safe living and working environment. Currently, there is no reliable air quality monitoring system that meets NASA's stringent requirements for power, mass, volume, or performance. The ultimate objective of the project—the development of a Real-Time, Miniaturized, Autonomous Total Risk Indicator System (RT-MATRIX)—is to provide a portable, dual-function sensing system that simultaneously determines total organic carbon (TOC) and individual contaminants in air streams.

TOC is often used as an indicator of organic contaminants in both liquid and vapor phases. On Earth-bound applications, TOC is analyzed in liquid samples either by catalyst or ultraviolet (UV)-promoted persulfate oxidation or by catalyst-assisted high-temperature combustion of organics. TOC in the gas phase is analyzed by flaming ionization of organics, followed by nondispersive infrared detection. Several types of flame ionization detector-based hydrocarbon analyzers are commercially available. They have been used for real-time monitoring of the effluent of volatile-contaminant reduction equipment for environmental compliance, lower-exposure-limit monitoring, and fugitive-emission monitoring. Unfortunately, the smallest available system weighs 55 to 65 pounds and measures 19×21×9 inches. Such TOC analyzers require carrier and fuel gases (hydrogen, air, or oxygen) for operation and have high power consumption (750 watts), which make them unsuitable for application in a space environment.

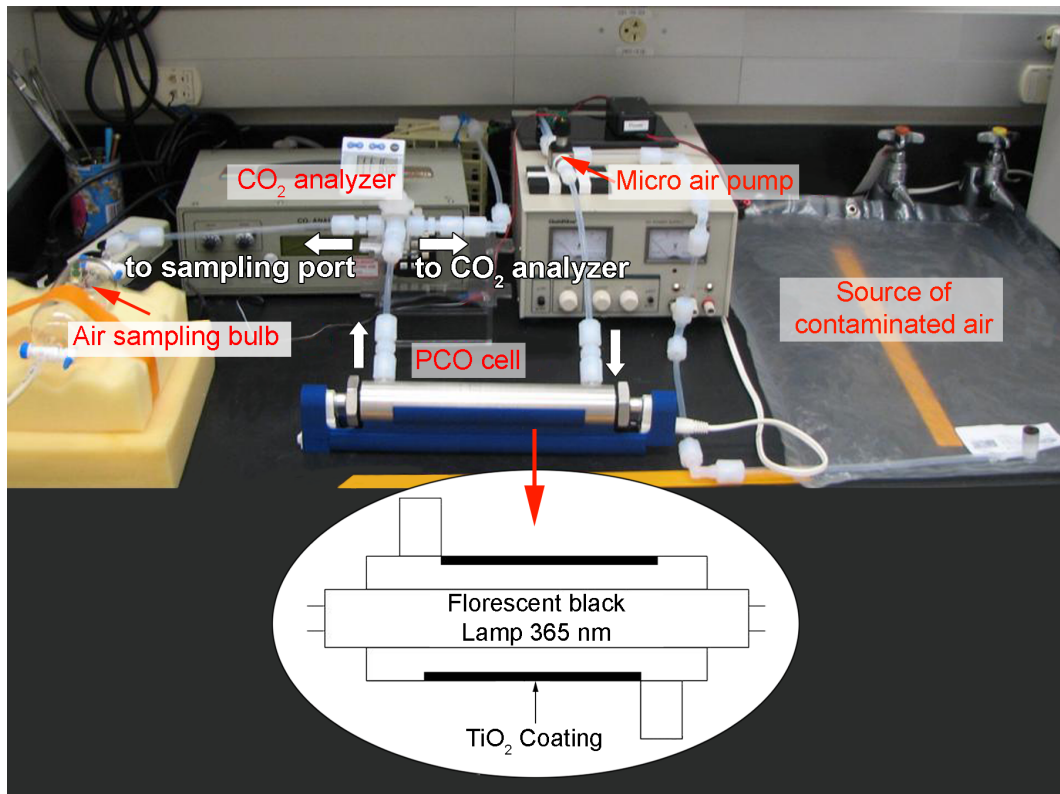


Figure 1. Experimental setup for evaluation of PCO cell performance.

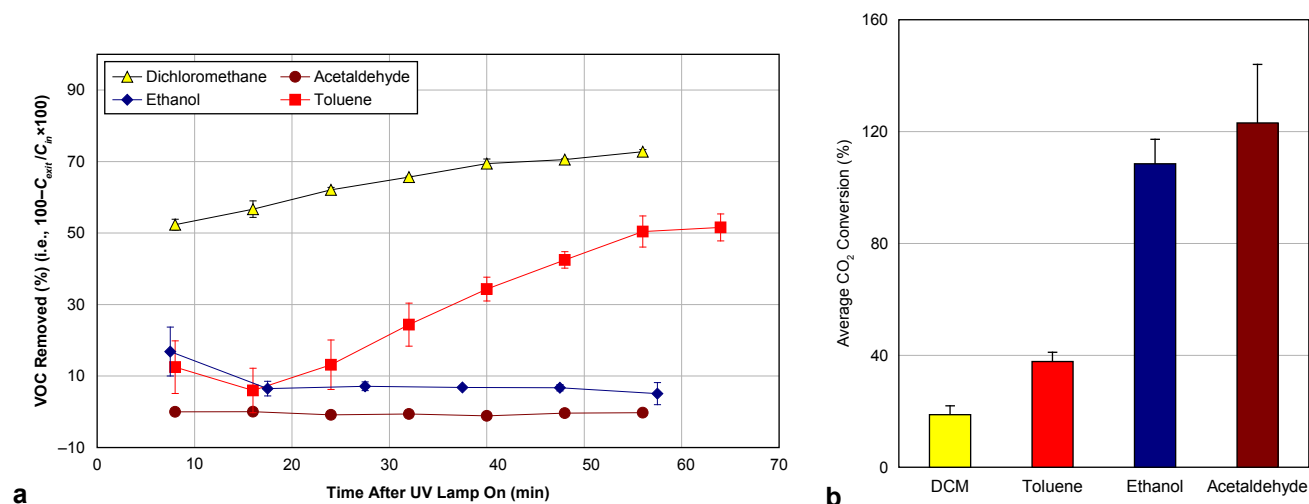


Figure 2. Photocatalytic oxidation of a constant flow (0.2 L/min) of 100 ppm toluene, dichloromethane, acetaldehyde, and 500 ppm ethanol; (a) VOC removed upon single pass through PCO cell; and (b) corresponding CO₂ formation.

Photocatalytic oxidation (PCO) of organic pollutants consumes less power, uses a nontoxic catalyst, and can destroy most organic pollutants. This technology has been employed in air revitalization systems. However, it is not known whether organic compounds are stoichiometrically oxidized into carbon dioxide. The concept of using PCO for TOC determination was tested. A prototype PCO cell (Figure 1) was constructed and evaluated against four VOCs representing alcohol, aldehyde, aromatic, and halogenic compounds. Representative results are summarized in Figure 2. Ethanol and acetaldehyde were oxidized almost completely upon single pass through the PCO cell, as is evident by the low level of starting material in PCO cell effluent and the formation of carbon dioxide at 100 percent of the theoretical conversion. However, the percentages of toluene and dichloromethane oxidized were about 80 and 50 percent initially and declined over time. This decreased oxidation may be attributed to the formation of intermediates that compete for the active site on the titanium dioxide catalyst. Over 50 minutes, the carbon dioxide conversion efficiency (i.e., actual [carbon dioxide]/expected [carbon dioxide] × 100) was about 40 and 20 percent for toluene and dichloromethane, respectively. The effect of linear velocity and surface area on the oxidation efficiency was also examined. Based on these preliminary results, a new PCO cell with improved performance was designed and is under construction.

We plan to couple this PCO cell with a commercial off-the-shelf (COTS) encoded photometric infrared (EP-IR) spectrometer to provide early detection of harmful VOCs and equipment leaks and to monitor the efficacy of air revitalization and solid-waste management systems. This dual-function sensor is portable and reagent-free, has no consumables, and is ideal for field application.

The project demonstrated stoichiometric conversion of select VOCs (e.g., ethanol and acetaldehyde) into carbon dioxide, implying the feasibility for PCO of VOCs as an alternative means for TOC measurement. Furthermore, a COTS EP-IR was acquired as our sensing component.

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