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Detection of greenhouse gas precursors from ethanol powered vehicles in Brazil

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ABSTRACT

The use of fossil fuels on the transport sector has caused the emission of various air pollutants, which can cause numerous damages to the atmosphere and to human health. In order to minimize pollutant emission, Brazilian government has encouraged the use of alternatives fuels, such as ethanol. Ethanol can be a great ally in global warming mitigation due to its potential to reduce carbon dioxide emissions in its renewable cycle.

Otherwise, other pollutant gases emitted during ethanol combustion can contribute directly or indirectly to intensify global warming. In this study, Photoacoustic and Electrochemical sensors were used to detect greenhouse precursor gases, such as carbon monoxide, nitrogen oxides and especially ethylene, a primary pollutant in the generation of tropospheric ozone, in the exhaust of ethanol powered vehicles, in the range of ppmv.

1. Introduction

As modern society becomes increasingly dependent on energy consumption, environment seems to go bankrupt in this system. Among all the environmental problems generated by the production and use of energy (mainly fossil), air pollution has received considerable importance in the world scenario due to its complexity and scope. The use of fossil fuels for energy production has caused many problems in local and global scale, such as human health problems, acid rain, photochemical smog and global warming [1–3].

Among the anthropogenic activities responsible for the emission of pollutants, the transport is highlighted because of the significant increase in the number of automotive vehicles around the globe. In an attempt to reduce vehicular pollutants emission, Brazilian government has strengthened the use of ethanol. The Brazilian ethanol program is supported by 2 basic factors: the mandatory use of ethanol blend in gasoline, and the expanding market for flex-fuel cars. The gasoline sold in Brazil has 20%–25% of anhydrous ethanol, and approximately 90% of the new cars sold use flex fuel engines [4].

Recently, ethanol has received great media attention, being targeted as a potential replacement for gasoline in the auto industry. Ethanol is a renewable fuel and can reduce considerably the emission of carbon dioxide (CO_2). This reduction occurs because, during the growth of the plant used in ethanol production, the CO_2 emitted in combustion process is

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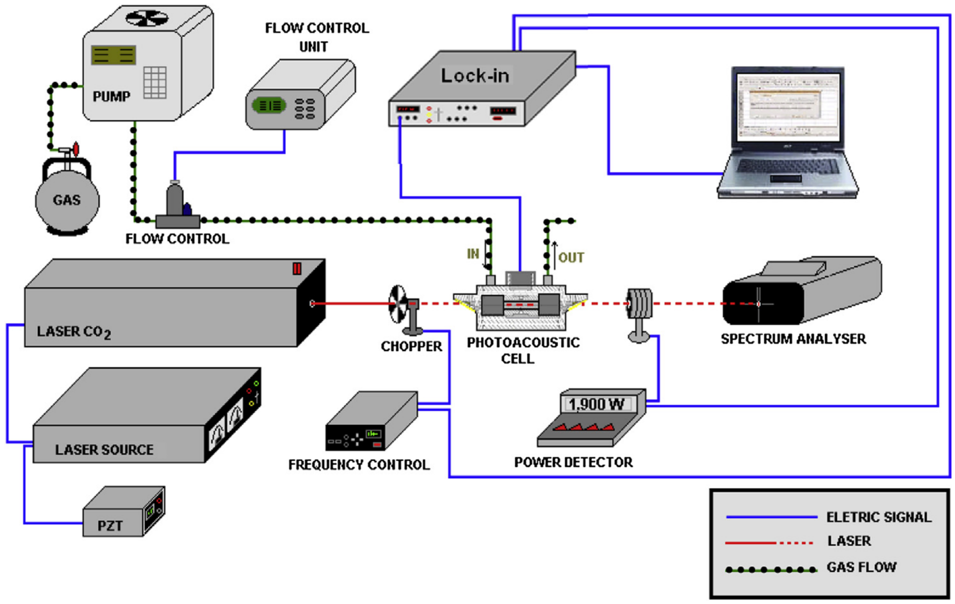

Fig. 1 – Scheme of the CO_2 Laser based photoacoustic experimental setup.

removed from the air through photosynthesis [5,6]. Ethanol can be produced by the fermentation of sugar or starch, which are present in large quantities in certain plants, such as sugarcane, corn, sugar-beet and sorghum. Ethanol can also be produced by the hydrolysis of lignocellulosic materials present, for example, in sugar cane bagasse and straw and in the wood. Despite the strong government incentive to use ethanol, some studies have demonstrated that this fuel also emit harmful air pollutants, just as carbon monoxide (CO) and nitrogen oxides (NO_x). These pollutants can occasion health problems, besides from occasioning the acid rain. Ethanol powered vehicles also emit other toxic pollutants, as formaldehyde and acetaldehyde [7].

However, conducting further research is needed to better evaluate the emission of pollutants emitted during the use of ethanol. In the present study, we evaluated the emission of greenhouse precursors, such as ethylene (C_2H_4), NO_x and CO in ethanol powered vehicles. It is well known that ethylene is a reactive pollutant, since it is an unsaturated organic compound. Ethylene, combined with nitrogen oxides, is a primary pollutant in the generation of tropospheric ozone. The tropospheric ozone is one of the main constituents of the photochemical smog, which affects directly the human health [8,9]. Other symptoms include coughing and breathing difficulties. Besides, it is a powerful greenhouse gas, whose formation is greatly potentiated by the incidence of sun radiation and the presence of nitrogen oxides (NO_x) [10,11]. According to the Intergovernmental Panel of Climatic Changes [1], ozone presents a positive radiative forcing of about 0.35 W/m^2, being an important source of global warming.

Thus, it is very important to evaluate the emission of tropospheric ozone precursors, such as ethylene and nitrogen oxides. Studies have detected the presence of ethylene in the exhaust of diesel [12] and biodiesel [13] powered vehicles using photoacoustic technique. Another study detected the presence of ethylene in gasoline powered engines [14]. Nevertheless, it is necessary to evaluate the presence of this pollutant in the exhaust of ethanol powered vehicles.

Carbon monoxide (CO), another pollutant emitted by ethanol engines, is not considered a direct greenhouse gas, but it is able to influence the production of methane and tropospheric ozone, which are important greenhouse gases [15–23].

In this work, Photoacoustic technique using CO_2 and Quantum Cascade Lasers was employed to detect ethylene in the exhaust of ethanol powered vehicles. Photoacoustic represents an excellent technique to track environmental gases for supplying many requirements to gas detection, such as high sensibility, spectral selectivity, multi-component detection and good temporal resolution [24–27].

The Electrochemical Analyzer TEMPEST 100, in turn, allowed the detection of NO_x and CO in the range of ppmv (parts per million by volume) in the exhaust of ethanol powered vehicles.

2. Methodology

2.1. *Photoacoustic detection of Ethylene*

In this work, a CO_2 Laser Photoacoustic Spectrometer (Fig. 1) was used to quantify ethylene in our samples. In the photoacoustic technique, the incidence of modulated light upon a gaseous sample, locked inside a closed chamber, induces sound waves which can be detected by highly sensitive microphones placed inside the chamber. The incident light wavelength must match the specific absorption wavelength of the species one wants to detect inside of the sample in order to promote absorption. In photoacoustic, this absorbed energy is released non-radiactively in the form of translational kinetic energy of the molecules, that is, heat. As the incident light is modulated, the periodical cycle of heating and cooling induces