# A Multi-Species Air Monitoring Laser Sensor Based on Absorption Spectroscopy and Machine Learning

AlDajani, Basheer (School: Dhahran Ahliyya School)

Eastern Saudi Arabia is home to Jafurah, the largest domestic unconventional non-associated gas field. The air surrounding this facility must be monitored effectively to prevent life-threatening leaks. Conventional methods, such as gas chromatography (GC), are bulky, expensive, and high maintenance. The objective of this work was to develop a portable and cost-effective multi-species laser sensor. The targeted species were benzene, ethylene, methane, and water vapor due to their significant indication of air quality, especially in gas fields and petrochemical refineries. The sensor was constructed using a mid-IR inter-band cascade laser, operating near 3.3 μm, and off-axis cavity-enhanced absorption spectroscopy. It was calibrated with 25 mixtures of various concentrations of the targeted species, and tested on 11 local air samples collected from 4 locations. Then, at various signal-to-noise ratio values, a partial least squares regression (PLSR) machine learning model was trained on simulated absorption spectra to optimize measurement accuracy. The sensor achieved a 2-ppb detection limit over a 6-second integration time. It outperformed GC with a lower coefficient of variation, higher accuracy, faster speed, and better repeatability. Additionally, the novel laser sensor was evaluated at 15% the price and 5% the size of a typical GC. The mean absolute detection errors were 4.1% for benzene, 21.6% for ethylene, 2.2% for methane, and 7.8% for water vapor. PLSR significantly reduced these errors in simulation to 0.43%, 2.9%, 0.41%, and 0.15%, respectively. These promising results may pave the way for a definitive breakthrough to perform necessary, sensitive, and selective measurements in applicable industries.