Soil gas monitoring system using low-cost sensors

Introduction

Abandoned oil and gas wells provide a potential pathway for subsurface migration and emissions to the atmosphere of methane and other fluids [1]. Paths of potential methane leakage include point and line sources such as boreholes and faults, area sources caused by diffusion or permeation across the sealing rock formation, or a combination of both [2]. The risk of leakage from boreholes and faults is of concern as they could provide conduits from the target formation directly or indirectly to the surface [2,3]. Air quality has a tremendous effect on public health and the environment [4]. Methane (CH₄) is an important trace gas, and its contribution to the greenhouse effect is estimated as high a 30% [5]. Methane in its gas form is an asphyxiant, which in high concentrations may displace the oxygen supply needed for breathing, especially in confined spaces. Methane is primarily produced in waterlogged anoxic soils by methanogenic archaea via methanogenesis [6]. One of the primary tools for assessing air-soil pollution patterns is continuous monitoring of pollutants’ ambient levels.

Methods

Y-POD devices were used for the Soil Monitoring Systems, that employ low-cost NDIR, metal oxide and electrochemical type gas sensors as well as temperature, pressure, and humidity sensors. The sampling systems were comprised of a stainless-steel probe, (diameter 1.2 cm), leading to an enclosure with gas sensors. Each probe was installed at 1-meter depth and a pump was used to draw air (1L/min) from the probe to a sensor enclosure.

Lab - Field deployment and Calibration

The lab calibration system used mass flow controllers and solenoidal valves to inject specific mixtures of gas standards into a Teflon-coated aluminum chamber equipped with temperature and humidity control.

The Y-POD low-cost platforms were also collocated with a Picarro instrument in Greeley, operated by Katie Benedict and Jeff Collett from Colorado State University Department of Atmospheric Science.

• \( \text{voltage} = p_1 + p_2 \cdot \text{concentration} + p_3 + p_4 \cdot (\text{absHumin}) \)

• \( \text{voltage} = p_1 + p_2 \cdot \text{concentration} + p_3 + p_4 + (\text{absHumin}) + p_5 + (\text{time} - \text{time}0) + p_6 + x \cdot (\text{time} - \text{time}0) \)

Results: Field Calibration

Conclusions

- We have studied commercially available low-cost gas sensors by evaluating their performance in a soil gas monitoring system. Laboratory calibrations were performed with gas standards in controlled ambient conditions and field calibrations were performed. Calibration relationships were developed by multiple linear regression. Sensor signal, measured Y-Pod enclosure temperature, absolute humidity, and time, were all used to inform the reference gas concentrations.

- A relationship is observed between CH4 and temperature (T). The highest values of T correspond to highest CH4 values, but not with CO2 values. The lower humidity values correspond to higher CH4 and CO2 values. The gas concentrations differ at the three locations, in connection with soil characteristics and chemical properties. To conclude we do not have outliers in this dataset, however a more thorough study is required.

Works Cited


Ana M.C. Ilie 1, Joanna G. Casey 2, Evan Coffey 3, Michael Hannigan 4, Carmela Vaccaro 5 | 1,2,3,4 University of Colorado Boulder, Mechanical Engineering | 5 University of Ferrara, Earth Sciences