Autonomous remote gas sensor network platforms with applications in landfill, wastewater treatment and ambient air quality measurement

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Abstract:

The composition of gas emissions from any natural or manmade process can reveal significant information about that process and can have a profound effect on the surrounding environment. Measuring gas emissions can expose previously unknown interactions between the process inputs as well as allowing the user to monitor the current state of the system. It is important to be aware of such emissions as carbon dioxide (CO_2) is a greenhouse gas (GHG) and can asphyxiate if allowed accumulate in a low-lying area. Methane (CH_4) is an even more potent GHG with a global warming potential 25 times greater than that of CO_2 (IPCC, 2007), and poses a fire risk when existing in the highly flammable range of 5-15% v/v in air. In the context of wastewater treatment plants (WWTPs), measuring the CO_2 and CH_4 emissions from an anaerobic lagoon can be used to monitor gas concentrations which can enable the bio-digestion processes to be optimised, thus ensuring they remain within safe levels. For example, the gas emission levels can be reduced by modifying the chemistry of the process, or by water agitation. Eventually it could drive the decision to enclosure the pond and burn the biogas, an action that can lead to carbon credits. Similarly, with landfill GHG emissions, monitoring CO_2 and CH_4 is very important as they must remain below the threshold levels set by the Environmental Protection Agency (EPA), i.e., 1.5% and 1.0% respectively (EA, 2004). Such thresholds warn about leakages on the lining of sites where the biogas is captured for energy generation purposes.

The typical practice of measuring greenhouse gas emissions requires a hand-held system (e.g. GA2000, Geotechnical Instruments) which must be carried on site and connected to the extraction pipe or well at each point of interest. This procedure is laborious and time-consuming, requiring travel over difficult terrain and resulting in infrequent and costly gas monitoring (typically once per month, or longer). To address these issues, autonomous wireless gas sensing platforms have been developed (Collins *et al*, 2013), multiples of which can be deployed across a landfill/WWTP to sample CO_2, CH_4 and pressure at sampling rates of up to 12 times per day. Subsequently, the data is sent to the cloud via GSM transmissions, and is accessible via an online portal for remote monitoring by the facility management and relevant stakeholders.

The development of autonomous sensing platforms requires long-term reliable performance (proven up to 12 months deployment before servicing) and reduction of component costs in order to allow scaled up deployments to be viable (Fay *et al.*, 2011). CO_2 and CH_4 sensing involves the use of high-accuracy infrared absorbance sensors, while piezoelectric sensors are used to measure pressure, which is critical for understanding gas flows throughout landfill extraction systems. Autonomous operation is achieved by custom-programmed microcontroller circuitry, which also manages data logging (onboard EEPROM memory chips) and remote transmission (GSM communications), as shown in Figure 1(a). The system components are housed within a robust weatherproof enclosure (rated to IP68) for long-term monitoring in what are typically harsh environments. Numerous deployments have been conducted in landfill facilities in Ireland, Scotland and in an anaerobic lagoon in a WWTP in

Brazil. The deployment of the gas monitoring system to São Paulo has been a collaborative effort between Dublin City University (DCU) and University of São Paulo (USP). The successful deployment of the autonomous gas monitoring system at a wastewater treatment plant in Mariporã administered by SABESP, with the employment of cloud-based data access tools demonstrating convincingly that it is possible to collaborate effectively on a global basis using such autonomous sensing platforms. In the deployment, a floating plastic accumulator bag was used to capture the emissions from the anaerobic lagoon which were then sampled by the gas monitoring platform. Over period of 28 days it was observed that the gas composition within the accumulator bag converged upon 4% and 22% for CO_2 and CH_4 respectively, see Figure 1(b). Such high magnitudes of potent greenhouse gases are of concern, particularly given that the highly potent methane was the dominant constituent. Other distinct events were clearly discernible in the time series data: an abrupt reduction in gas levels (figure 1(b); point ‘A’) coincided with movement of the accumulator bag, which allowed air to leak in. In addition, periodic daily fluctuations in gas levels were observed at the latter stages of the deployment (figure 1(b), point ‘B’), which correspond probably to the day/night gases inputs of sewage disturbing the benthonic zone and variations on near surface bacteria and algae respiration. The generation of these patterns, and the identification of factors underlying them has generated substantial interest from SABESP, as the capability to track these events has not been available up to now. Additional deployments are currently in progress in order to more fully understand how management of the anaerobic digestion process can be optimised.

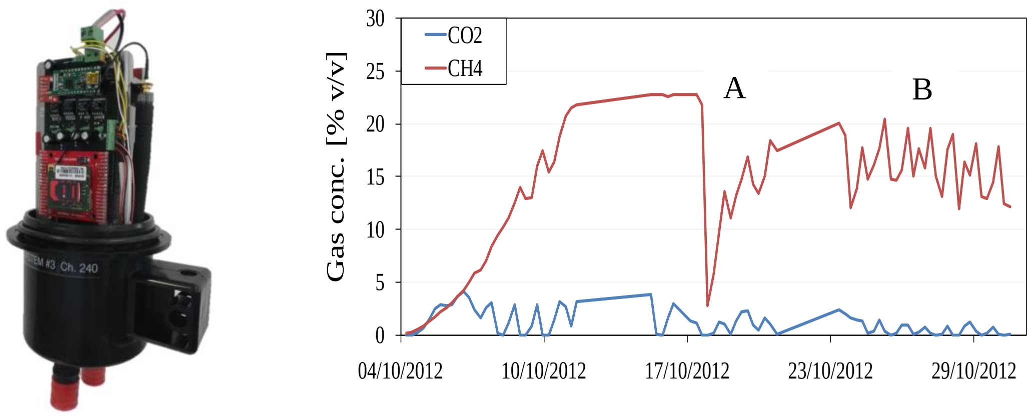

Figure 1. (a) Internal view of autonomous gas monitoring system (b) acquired data from gas emissions from WWTP lagoon in São Paulo

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