Microcontroller-Based Instrument for Measuring Methane Concentration

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Abstract

A portable microcontroller-based instrument for measuring methane concentration was fabricated using Atmega16 microcontroller. The TGS2611 methane sensor was interfaced into the system. The system was designed to automatically collect data from the sensor every minute, and store them in non-volatile memory for retrieval using serial interface to a personal computer. The study has four main parts namely hardware design, software design, calibration, and data acquisition and storage. The Atmega16 was used to perform the data collection, data storage, and data display and retrieval. The system was used to gather data on manure pits for two hourst. Methane concentrations ranging approximately 4000 - 12 0000 ppm were observed for the closed pit, while for an open pit the readings obtained ranges from 75 - 17 000 ppm. Also the device was exposed with fixed methane concentration of 8000 ppm and the sensor's reading stabilized after a certain time and the results are very precise with the standard. From the results, it shows that the device an be used for monitoring methane concentrations.

1. Introduction

Methane (CH_4), a product of microbial degradation of carbonaceous materials, is not a poisonous gas. Rather, it is biologically inert and produces effects on animals only by displacing oxygen in a given atmosphere thereby producing asphyxiation. Under ordinary pressure, a concentration of 87-90% CH_4 in a given atmosphere is required before irregularities of respiration and eventually respiratory arrests due to anoxia are produced [1].

Methane is an important greenhouse gas and a major environmental pollutant. It is also the primary component of natural gas and valuable energy source. One of the major sources of methane is biomass.

Biomass refers to all organic matter generated through. Photosynthesis and other biological processes. It applies to the mass of substance generated by the growth of living organisms, be they microorganisms, plants and animals [2]. When organic matter decomposes in the exclusion of air it produces biogas and sludge, and this process is called biogasification. The biogas is composed of methane, carbon dioxide, some hydrogen and minute amounts of hydrogen sulfide. There are different sources of biogas. Major sources of biogas can be found from sewage, solid wastes and animal manure.

The Philippines has many animal farms that produce biogas. Methane emissions from anaerobic digestion constitute a wasted energy resource which can be recovered by adapting manure management and treatment practices to facilitate methane collection. This methane can be directly used for on-farm or for sale [3].

Methane's increasing concentration is the atmosphere has important implications for global climate change. It is very effective at absorbing infrared radiation reflected by the earth's surface. It has been estimated that approximately 18% of the greenhouse effect due to increasing atmospheric methane concentrations. The total contribution to radiative forcing of all greenhouse gases in 1990 is shown in Figure 1 [3].

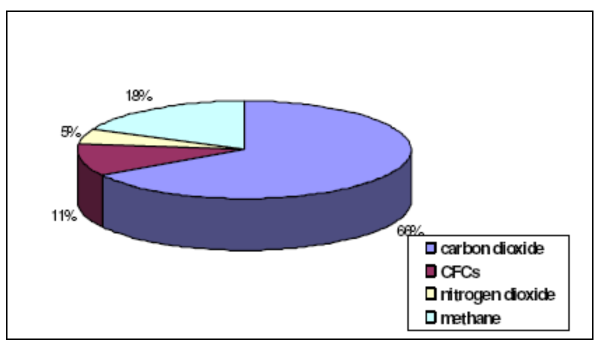

Figure 1. Global contribution to integrated radiative

Portable instruments are very indispensable in monitoring purposes. A microcontroller is a very useful device in the fabrication of a portable monitoring instrument. In this study, a portable microcontroller based instrument for monitoring methane concentration in swine manure pits was constructed. It should be noted that monitoring is done in the actual field sites, and therefore, a portable microcontroller based device could be of great help in such activities.

2. Methodology

To monitor the methane concentration in a certain area, the TGS 2611 methane sensor was used. In a similar study, TGS 826 ammonia gas sensor was used by [4] in order to detect ammonia gas level in swine fields in which they studied the optimum level in which ammonia concentration is still safe. For our study purpose, a microcontroller board was constructed to acquire sensor readings and store it in a non-volatile memory. The study consists mainly of 4 parts: hardware design, software design, calibration, and data gathering.

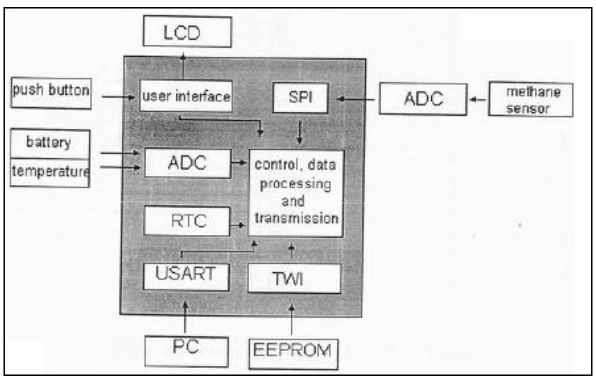

Figure 2. Microcontroller-based for measuring concentration block diagram

Figure 2 shows the diagram of the whole set-up. It consists mainly of the microcontroller unit, external ADC, external non-volatile EEPROM, PC interfacing board, real time clock and the user-interface module.

The interface of the device with the computer consists of the MAX232 line driver IC and four 1uF electrolytic capacitors. The chip is connected to the RX and TX pins of the controller chip and to a DB9 female connector. The schematic diagram is shown in figure 3.

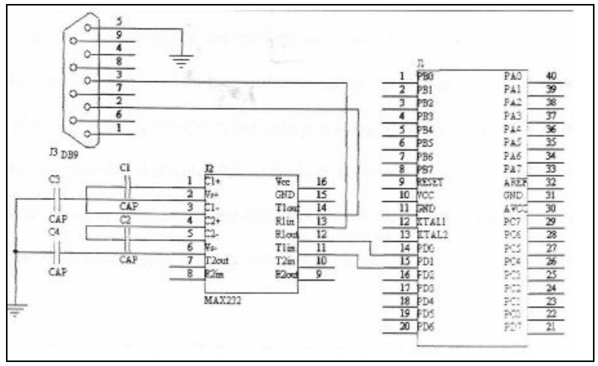

Figure 3. Schematic diagram for interfacing to the pc serially

The TGS 2611 methane sensor is connected to the ADS7813, a 16-bit ADC through the Serial Peripheral Interface (SPI) of the Atmega16. The change involtage is then directed to the ADS7813. To calibratethe sensor, the methane sensor was exposed to different methane gas concentrations, in which the corresponding voltage output of the sensor for each concentration was monitored. Gas collection was first done using test tubes with seal. Using Gas Chromatography, the gas concentrations were then analyzed, and the sensor also measured the corresponding concentrations.

Data sampling and testing was done at the University Animal Farm of the Institute of Animal Science. The device was exposed to swine manure lagoons, in which the data was stored in a EEPROM inside the device to be retrieved later for analysis purposes.

3. Results and Discussions

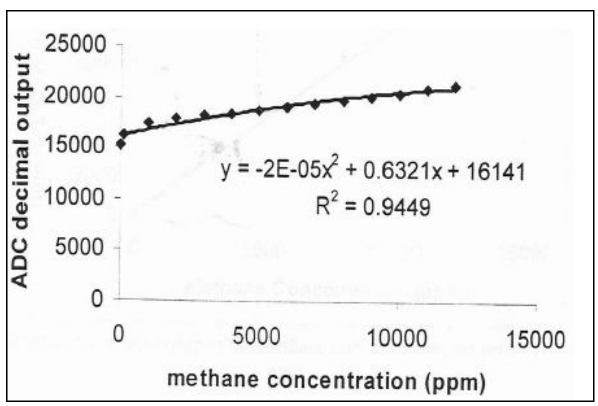

Figure 4. Plot of the calibration curve of ADS7813 16-bit analog to digital converter (ADC)

Shown in figure 4 is the calibration of the 16-bit analog to digital (ADC) converter ADS7813 which was done by plotting the ADC decimal output stored in the EEPROM with methane concentration. Since ADS7813 was used with internal reference voltage configuration (2.5 V) and is a 16-bit converter, its voltage increment per one decimal increment is 61 micro volts.

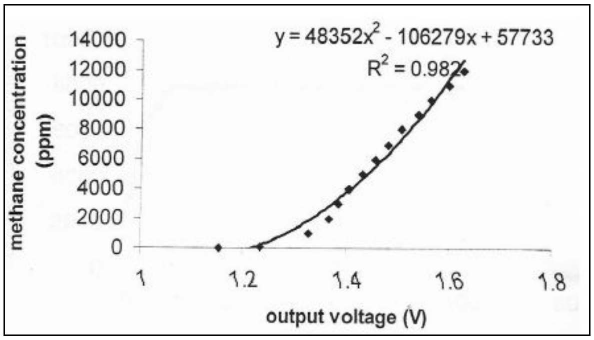

Figure 5. Plot of the sensor's output voltage against standard methane concentration

The methane sensor TGS 2611 was calibrated using standard concentrations of methane in order for it to be suitable for monitoring purposes. Figure 5 shows the plot of methane concentration versus sensor's converted reading. The obtained relationship is approximately a second order polynomial function with R2 = 0.982, which is in agreement with the sensor's optimal response as stated in the data sheet [5]. The theoretical resolution of the sensor was calculated at 2 ppm. This was done using the typical range of the sensor. The resolution defines the system's precision. The system's response time varies according to the model of the sensor and the gas involved [5]. The sensor was exposed to standard methane concentrations and the corresponding output voltage was taken into consideration. The transfer function obtained was used for the conversion of the voltage output to its equivalent concentrations in parts per million (ppm) shown n figure 6.

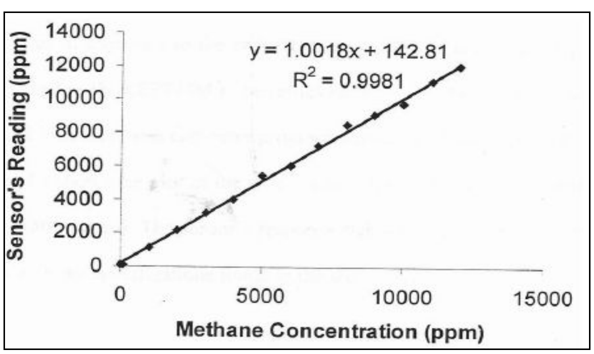

Figure 6. Graph of the relationship of methane concentration and sensor's reading in ppm

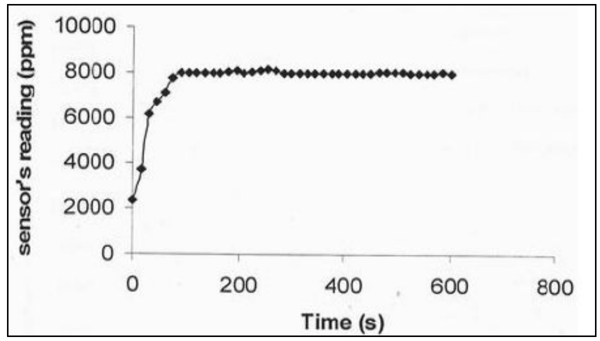

Figure 7. Response curve of the sensor as exposed to 8000 ppm methane gas concentration

Figure 7 shows the plot of the sensors concentration reading against a fix gas concentration (8 000 ppm). The sensor's response stabilized after a certain time, which is in agreement with the specifications in the data sheet.

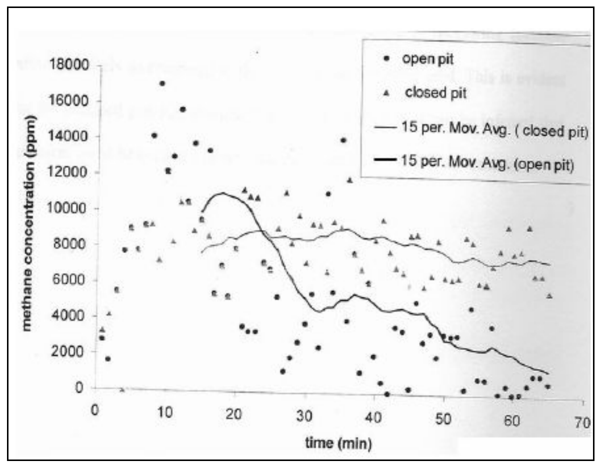

Figure 8. Comparison of methane concentration in open and closed manure pits with moving average

Figure 8 shows the plot of the methane gas concentration versus time in the swine open manure lagoon, monitored for 60 minutes in one minute interval. It can be seen from the plot that the swine lagoon exhibited a maximum methane concentration of approximately 17 000 ppm, while the lowest concentration obtained was approximately 75 ppm. From these results, it can be observed that methane concentration in the swine field greatly increased. Also shown in figure 8 (in triangular points) is the log plot of methane concentration in an enclosed manure pit. From the plot, it can be observed that there is a more stable set of concentrations compared to the one gathered in an open pit with values ranging from 4000 ppm to 12 000 ppm. It can be observed that there is a variation in the data observed. The observed fluctuations could be attributed to several factors such as the change in methane concentration, weather conditions and characteristics of the gas. Since methane is a volatile gas one factor that could have affected the results is diffusion. Since the lagoon is open, methane can diffuse easily to its surrounding due to a high concentration gradient. It could be observed that there are values measured that go beyond the optimum sensitivity of the sensor as stated in [5]. This could be due to the inherent sensitivity of the sensor to other gases which results to the measured value. However, in terms or monitoring purposes, we can be sure at least, that the resulting trend is due to methane, which is the gas that the sensor can sense the most.

Observing the results, it could be said that the device is capable of measuring methane concentrations. With this it can be inferred that the measurement could be used as a monitoring instrument for methane concentration.

4. Summary, Conclusions and Recommendations

A microcontroller based instrument for measuring methane was designed. It was tested in a swine lagoon where swine manures are disposed. The sensor used was the TGS2611. The system was designed to collect data automatically every minute and saved it in a EEPROM memory which could be retrieved. The sensor calibration was done by plotting the system's voltage output versus the known methane concentration, in which the response observed was a second order polynomial function.

The device was tested through data acquisition in an open and closed manure pit for one hour. Higher concentrations of methane were observed for the enclosed manure pit. The concentrations observed for the open lagoon have a decreasing trend, which could be attributed to several factors including temperature differences and space occupied which could have result to diffusion.

It is recommended that the time interval for logging should be small so that data to be obtained has less abrupt changes. By doing this, the systematic increment and decrement of methane concentrations can be observed. Furthermore, the device could be tested in different places like garbage sites and septic tanks with differences in parameters and conditions.

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