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Performance Comparison of a Low Cost Air Quality Sensor with a Commercial Electronic Nose

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***Abstract*—**The Figaro AM-1 sensor module which employs TGS 2600 model gas sensor in air quality assessment was used. The system was coupled with a microprocessor that enables sensor module to create warning message via telephone. This low cot sensor system's performance was compared with a DiagNose II commercial electronic nose system. Both air quality sensor and electronic nose system employ metal oxide chemical gas sensors. In the study experimental setup, data acquisition methods for electronic nose system, and performance of the low cost air quality system were evaluated and explained.

***Keywords*—**Air quality, electronic nose, environmental quality, gas sensor.

I. Introduction

AIR quality monitoring and assessment in livestock buildings has been a concern amongst agricultural engineers and veterinarians due to its effects on livestock environmental quality and health conditions [1]. There are many airborne microorganisms effect not only animal health and welfare but also workers' health. Some of the major airborne microorganisms are *Pseudomonas*, *Bacillus*, *Corynebacterium*, *Pasteurella*, *Vibrio*, *Enterobacter*, *Salmonella*, *Brucella*, *Leptospira*, *Hamophilus*, *Mycoplasma*, *Yersinia*, *Staphyloccocus*, *Streptococcus*, *Micrococcus*, *Pantoea* and *Sarcina* species [2].

There are different technologies available to monitor livestock air quality including photoacoustic infrared (PIR) CO2 analyzers, fluorescence-based H2S analyzers, photoacoustic multigas analyzers (PAMGA), nonmethane hydrocarbon analyzers [3], electronic nose systems [4], and Gas Chromatography coupled with Mass Spectrometry (GC/MS).

Determination of baseline emission data is critical in agricultural air quality. With the recent advancement in computers and electronics it is possible to obtain, store and evaluate data for longer time periods. There were research projects involved millions of dollars of cost to monitor air quality data [5].

Another way of assessing air quality is monitoring odor in the building envelope. An odor is the mixture of airborne molecules in different sizes and varying concentrations. A wide range of sensor technologies are also available including conducting polymers, piezoelectric devices, electrochemical cells, metal oxide sensors (MOX) and metal-insulator semiconductor field effect transistors (MISFETs) to evaluate the odorous air [6].

In this study it was aimed to evaluate the performance of a low-cost air quality sensor module. To achieve this goal, the sensor module was exposed to different levels of odor. The results were compared to e-nose readings.

II. Materials and Methods

A. *DiagNose II Electronic Nose System*

The experiment was conducted at the Agricultural Sensor and Remote Sensing Laboratory (ASRESEL) of Çanakkale Onsekiz Mart University, Çanakkale/Turkey in 2015. A DiagNose II (The eNose Company, Zutphen, Netherlands) e-nose system was used in the study. The system employs 12 intelligent metal-oxide (MOX) gas sensors (Fig. 1) and each sensor module contains driving electronics, microprocessor and a unique silicon serial number.

Fig. 1 DiagNose II e-nose system

The sensor array is capable of detecting a wide range of volatile hydrocarbons and inorganic substances. Examples of the inorganic substances are H_2S, NO_x, SO_x, NH_3, Cl_2, and O_3. Some of the organic substances that could be detected are light alkanes, alkenes and alkynes, light alcohols and aldehydes, light amines and mercaptans, partly halogenated hydrocarbons, volatile acids, volatile aromatics.

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The temperature modulated MOX sensors are in a working range of typically 180-340°C. Within this range the sensors operates as semiconductors. The conductivity of the sensing element is low when oxygen adsorbs and/or ionizes at the sensor surface. Reaction of oxygen with other substances (redox reaction) results in redox reaction that causes a measurable change of electrical conductivity. The change in conductivity is governed by the sensor material, sensor temperature dynamics and the chemical reaction rates.

B. Air Quality Sensor Module

An air quality sensor module of AM-1-2600 (Figaro Engineering Inc., Osaka, Japan) was used to monitor air quality (Fig. 2). The module employs air contaminant gas sensors TGS2600 and a microcomputer (FIC-02667) for automatic control of air quality control devices such as air cleaners and ventilators. The module does not measure the actual contamination levels. Instead, the output signal of gas sensor is compared to a benchmark level. The microprocessor receives the signals from gas sensor and evaluates pollution levels in four degrees accordingly. The microprocessor unit is able to compensate the effects of humidity, atmospheric temperature and transient gases on the sensor unit. It also can generate control signals for an air quality controller such as ventilation system.

After powering on, the module starts an Initial clean-up operation for two minutes followed by 3 minutes of high sensitivity operation. It finally goes to standard operation module.

a. Initial Clean-Up Operation

LED 1 (Good) blinks on and off regardless of pollution levels. At the end of this operation, LED 1 stops blinking remains on. At this stage the output signal level of the sensor is memorized by the microcomputer as clean air.

b. Standard Operation

The module in this mode indicates the degree of pollution with the LEDs, based on ratio of sensor resistance to the benchmark resistance value of ‘clean air’. The benchmark signal level for clean air in the microcomputer is periodically (factory preset is every 20 minutes) or manually reset. Technical specifications of the air quality sensor module are given in Table I.

C. Dual Tone Multi Frequency Signaling Module

The AM-1-2600 air quality module was integrated with a TD-200 (Paradox Security Systems, Istanbul, Turkey) dual-tone, multi-frequency signaling system (DTMF) (Fig. 3). The DTMF is an in-band telecommunication signaling system using the voice frequency bands over the telephone lines to control applications interactively. In our application, as the air quality level changes the DTMF communicates with AM-1-2600 modules and generates phone calls to warn the person of interest. The unit can call up to 8 different telephone numbers. The warning message can be recorded to the system.

TABLE I
SPECIFICATIONS OF AIR QUALITY SENSOR MODULE

Item	Specification	
Power supply	DC 5 ±0.2 V	
Power consumption	Max 0.8W	
Target gas	Indoor atmospheric pollution caused by deoxidizable pollutant gases	
Sensitivity (High/low)	3/6 ppm of H_2	
LED display	LED 1 (green)	Good
	LED 2 (red)	Polluted
	LED 3 (amber)	Low pollution level
	LED 4 (amber)	Medium pollution level
	LED 5 (amber)	High pollution level
Microprocessor output terminals	Active level	Low
	Max. output current	+20mA
Output terminal of +5V power supply	Max. output current	0.5 A
Operational temp. range	-10 ~ 50˚C, 5 ~ 70% RH	
Storage temp. range	-20 ~ 60˚C, 5 ~ 90% RH	
Dimensions	70mm x 70mm x 40 mm	
Weight	20 g	-

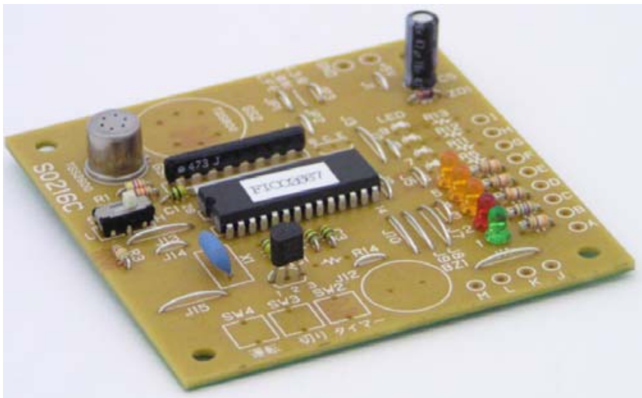

Fig. 2 Gas sensor module

Fig. 3 The DTMF unit

The sensor and DTMF modules were integrated to operate together in one system (Fig. 4).

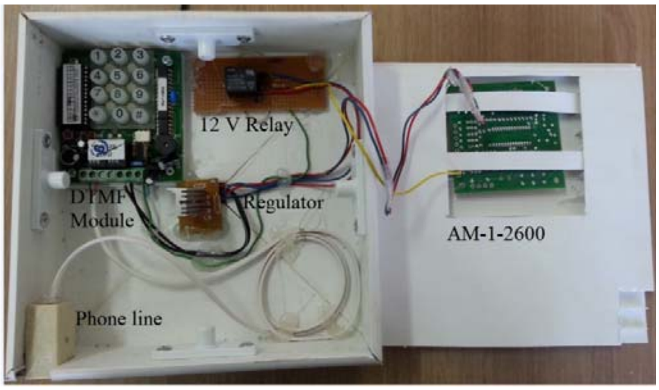

Fig. 4 Integrated air quality sensor module

D.Experimental Setup and Signal Processing

The experiment conducted in a 120 cm diameter cylindrical shaped pan (Fig. 5). Both electronic nose and gas sensor system located inside of the pan and covered with a glass cover. Manure sample was collected from a nearby dairy farm. Devices were powered up for warming up the sensors in both systems for about 5 minutes. In order to create a polluted headspace environment 500 g manure sample was placed in the middle of the pan and both systems started. In order to increase the air pollution level two more times 500 g manure samples were added to the pile. Before each manure addition the pan was ventilated to remove the headspace gases from the previous run. Thus, 3 pollution levels were created artificially.

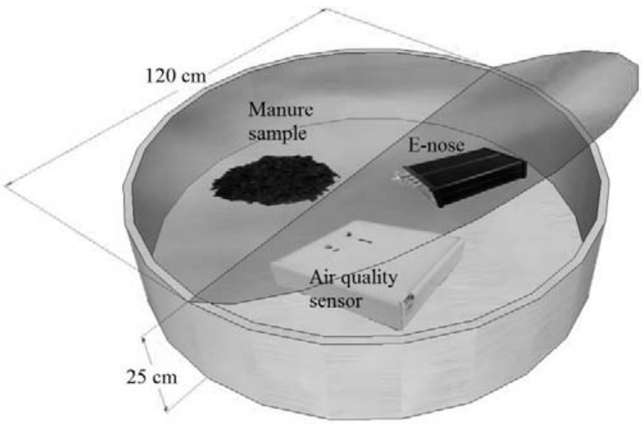

Fig. 5 Experimental setup

The e-nose sensor signals need to be transferred to the computer for further processing. DiagNose II was connected to the computer and sensor signals were downloaded in CSV format via EPA software (The eNose Company, Zutphen, Netherlands). The raw sensor signals for 3 experiments and 12 sensors within the e-nose were converted to XLS format for further processing. Signals were then normalized using (1) [7]:

$$V_n = \frac{V_i - V_{min}}{V_{min}} \tag{1}$$

A sample normalized sensor response curve indicating sensor operation phases are given in Fig. 6.

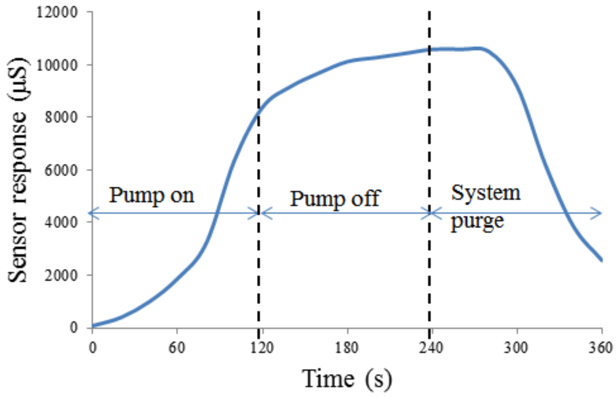

Fig. 6 A sample sensor response curve

III. Results and Discussion

E-nose and air quality module responses were needed to conduct a comparison between two systems. The normalized sensor response curves were plotted on the same graph (Fig. 7) in order to visualize the e-nose performance throughout the experiment. It was aimed to observe if the AM-1-2600 module is able to generate phone calls for 3 levels of pollution.

The results show that the sensors within the e-nose system sense the gas generation from manure samples. The peak levels indicate the time when sniffing ends and system purge starts. As the e-nose purges the sensors with clean air outside the pan, sensor responses starts a descending trend.

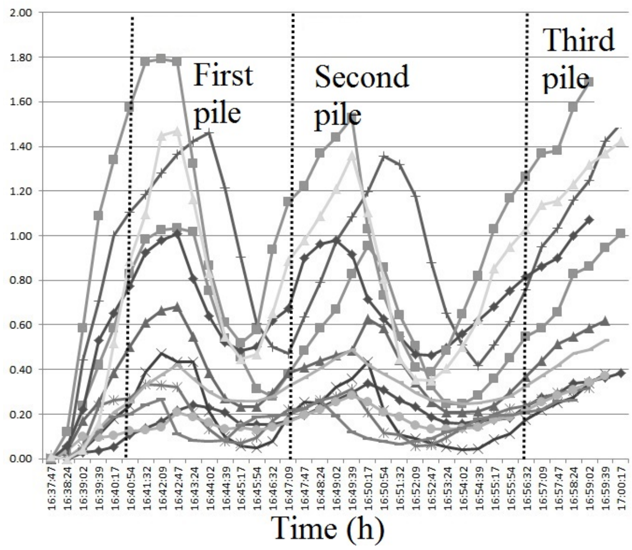

Fig. 7 Normalized responses of all sensors

In Fig. 7 vertical dashed-lines indicates the time when AM-1-2600 module responded to headspace gases and generated phone calls. It was noticed that in all readings the air quality sensor module generated phone calls about 1 minute after it was placed in the pan. It was also noted that after the addition of each manure piles to the pan, pollution increased to one upper level indicated by LEDs.

The ultimate purpose of our study was to develop a cost effective air quality warning system that can be used in livestock building. The cost of entire system was found to be around $ 150 which is highly affordable. Overall, this study showed that AM-1-2600 air quality sensor module integrated with a DTMF unit can be a cost effective solution in air quality monitoring and warning applications.

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