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Odour and Hazardous Gas Monitoring System for Swiftlet Farming using Wireless Sensor Network (WSN)

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The production of edible swiftlet nest is a growing industry in Malaysia; where farmers recreate the bird's habitat in buildings referred to as swiftlet houses. The conditions in these swiftlet houses are however, largely unknown as there seems to be lack of research effort in this newly formed industry. This paper presents the odour and hazardous gas monitoring system utilising wireless sensor network. Several gas sensor readings including humidity, temperature, luminance and rainfall were recorded in a swiftlet house in Arau, Perlis. A single sensor element was found to be insufficient to monitor a specific gas as the odour is a synergy, inhibition and masking between different compounds. Indoor and outdoor humidity and temperature variations were also investigated. The studies have shown that the sensor responses were affected by the odour resulting from different combinations of four different groups of compounds. Minimum threshold level is proposed to alert the breeder so that efforts to reduce the gas levels to a safe and comfortable level can be taken.

1. Introduction

The white edible bird nest (EBN) is made with saliva of *Collacalia Fuciphagus* or more commonly known as Swiftlets. It has been attracting interest, especially from the Chinese supposedly due to the high nutrient contents, minerals and anti-oxidants; believed to promote good health and increase longevity. The demand for edible swiftlet nests has continued to grow due to their nutraceutical values. To fulfil the demands, houses for swiftlets have been built to provide an artificial habitat in which these birds can build their nest and can be easily harvested. This artificial farming has raised a number of concerns. Very few researchers have studied and quantified the conditions of this swiftlet houses in terms of odour emissions and its impact on humans, the EBN and equally important the environment. Not surprisingly, safety and environmental regulation on this aspect is also non-existent.

Based on previous research on broilers, several gasses such as ammonia (NH_3), hydrogen sulphide (H_2S), carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4) are expected to be released from droppings, leftover feed and decomposing of carcasses (Mursec et al., 2009).These gasses can be harmful to humans if available in high concentrations (Casey et al., 2006). This also applies to the swiftlet farm. It may become a nuisance to the surrounding if this matter is not properly addressed. Furthermore, build-up and excessive concentration of these gases in an enclosed area of the swiftlet houses can be harmful either to humans or swiftlets.

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The swiftlet farming industry is expanding, thus, suggesting the need for a system to monitor or provide early prediction of odour concentration build-up. This study can be a reference for law makers to establish regulations to ensure a more hygienic condition in the swiftlet houses.

Since, odour is a synergy, inhibition and masking effect between different compounds, a single sensor is insufficient to monitor specific gases (Ishii et al., 2008). Multiple gas sensors were deployed to monitor if there were changes in concentrations of gas.

This research investigates the feasibility of deploying odour and hazardous gas monitoring system for swiftlet farm using Wireless Sensor Network (WSN). Instead of a single sensor, an array of three Metal Oxide Semiconductor (MOS) gas sensor was used to monitor the changes of hazardous compound in swiftlet house. Initial calibration on different mixtures of four different gasses (NH_3, H_2S, CO and SO_2) at 50ppm concentration was done. The deployed system is discussed in detail, including the design of the chamber, followed by results and discussion of the collected data and the performance of the system in general. The conclusion section will highlight the key points and suggest the future improvements of this system.

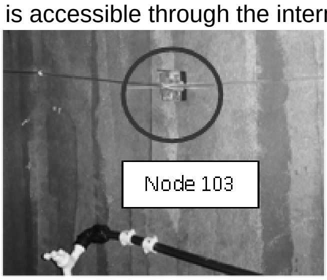
2. System Overview and Deployment

Swiftlet houses are in general a big enclosed area; the smallest usually being 30 m by 6 m feet and the biggest is of 100 meters by 20 meters size. WSN is preferred for ease of deployment, fast deployment and flexibility of the sensor placements. The swiftlets naturally are thought to be sensitive and easily intimidate by intruders. Hence, this application demands a fast deployed system to minimise human contact with the birds as shown in Figure 1. Wireless based systems allow sensor nodes to be placed anywhere without the need to wire everything up and also provides scalability. On the contrary, wired system may be susceptible to noise and voltage drops due to the distance of the signal path (Mechitov et al., 2004). The deployment of wireless sensor networks solved these issues.

Figure 1: Infrared images of the swiftlet roosting in the house during night time

2.1 Wireless Sensor Network Platform

The work presented in this paper used WSN modules from MEMSIC. There are two types of nodes used; the solar powered eKo Motes (EN2100) for outdoor weather station and iris motes (IRIS-XM2110). These nodes uses mesh technology to effectively create optimum data paths among the motes and channel data to the base station (Roberto et al., 2012). The data is transmitted to a local gateway server through a base station that provides WAN connectivity and data logging to the database. The data is accessible through the internet for remote monitoring.



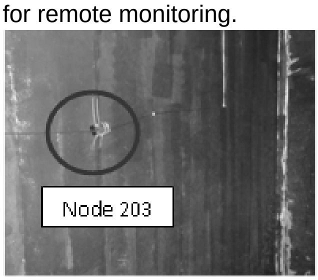


Figure 2: MTS 400 and MDA 300 wireless sensor nodes use in the experiment

Two types of sensor boards; MTS 400 and MDA 300 attached to the motes allow indoor and outdoor humidity, luminance and temperature to be recorded as shown in Figure 2. A weather station is also used to collect data on rainfall, wind speed and direction as shown in Figure 3.

Figure 3: Anemometer (as part of Weather station) is placed on the roof top

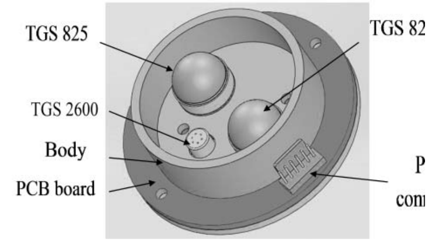


Figure 4: Gas chamber for gas monitoring system

2.2 Gas Sensing Module

Gas chamber is part of the gas sensing module. It has been specially designed to measure the ambient air in swiftlet farming as shown in Figure 4. The gas chamber is divided into two parts; body and printed circuit board (PCB) board. The shape of the gas chamber is cylindrical to enhance laminar airflow. The diameter of the cylindrical body is 60mm. The height of the chamber is 19 mm which is the same as the height of the sensor. This is to ensure that the gas can circulate freely within the chamber. Thus, the readings of the gas sensors will reflect the actual circulation of gas concentration in the swiftlet house.

Conversely, the gas sensor array consists of three MOS sensors from Figaro; which are TGS826, TGS 825 and TGS 2600 for ammonia gas, hydrogen sulphide and methane, respectively. These sensors were selected due to their ability in measuring the typical gases and malodour found in animal farms (Brattoli et al., 2011). MOS sensors are one of the low cost gas sensors that have been used extensively in electronic gas instruments for detecting and monitoring air quality (Hoffheins, 1996). Unfortunately, this type of sensor is susceptible to humidity and temperature changes. A small change in humidity of the ambient air may affect the sensitivity of the MOS sensor reading (Cavanaugh, 2002). Thus, indoor and outdoor humidity and temperature variation were also recorded for analysis. The gas chambers are installed in the swiftlet house at two specific locations particularly at 2.5 m and 0.75 m from the floor. Data was sampled every 15 min throughout the day for the duration of the experiment.

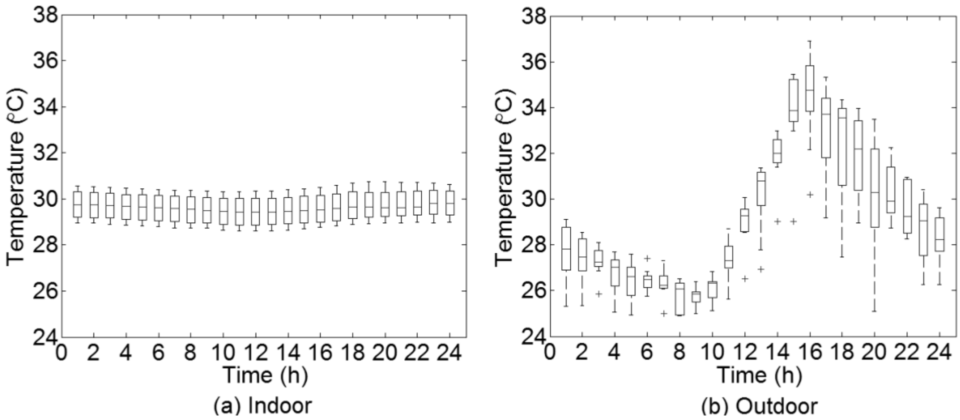


Figure 5: Indoor and outdoor temperature variation

3. Results and Discussion

3.1 Temperature, humidity and weather condition

The temperature, humidity and weather conditions were recorded throughout the whole day for the duration of experiment. A significant variation of the outdoor measurement has been observed compared to indoor temperature measurement as shown in Figure 5. However, no significant trends have been observed for indoor temperature. This is also true for indoor humidity trends (Figure 6a). The finding shows that the outdoor climatic behaviour does not affect much on the microclimate of the swiftlet house. This ideal condition enables the MOS sensor to operate without being affected by drastic changes of humidity and temperature. The rain pattern was also recorded as shown in Figure 7. It is useful to predict any drastic or sudden changes of humidity and temperature data.

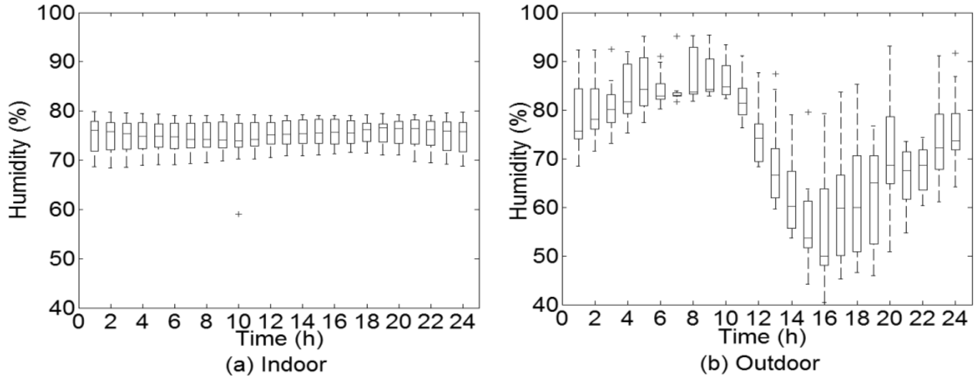


Figure 6: Indoor and outdoor humidity trends

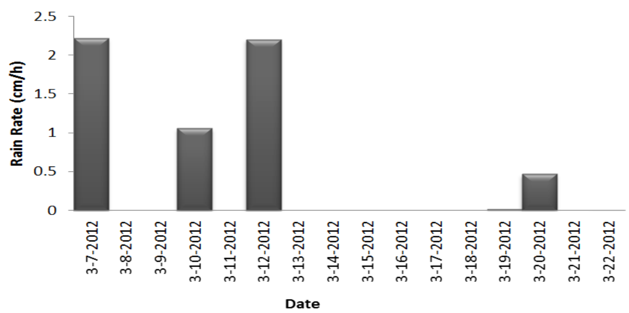


Figure 7: Raining pattern throughout the experiments

3.2 Odour measurements results

The three sensors were calibrated and exposed to the target analytes prior to deployment. The calibration data of the three sensors are shown in Table 1. Each gas with concentration of 50 ppm was exposed to the sensor until it reaches the steady state and later were repeated by exposed them to the mixture of gases. It is clearly seen that a single sensor element was found to be insufficient to monitor a specific gas in the presence of other gases. The 'masking effect' was observed on both TGS 826 and TGS 2600 sensors as there is no changes in reading with the presence of H_2S gas in the gas mixture. Based on these three sensors, the odour measurement was performed for a period of 15 days. The boxplot of three gas sensor readings (in mV) is shown in Figure 8. It is observed that the sensor readings obtained over the period were varying. This indicates that the concentration of ammonia, hydrogen sulphide and methane gases in swiftlet building fluctuated. It is also may be due to synergy, inhibition and masking effect of the present gases in the swiftlet house. Furthermore, the response of TGS 825 keeps on declining and it may indicate the increasing amount of ammonia level throughout the experiment. Slight increment of TGS 826 response at day 9 and 14 indicate the increment carbon monoxide level, which can be correlated with calibration results from the Table 1. Also, the recorded sensors readings exceed +/- 20 % margin of the baseline response. This indicates that the housekeeping is required to ensure that the gas levels are reduced to a comfortable level. There is no significant influence of temperature and humidity changes. Temperature and humidity trends are almost consistent throughout the experiments as shown in Figure 9.

Table 1: Sensors calibration

Analytes	Gas sensor reading (V)		
	Air Contaminant (TGS 826)	Air Quality (TGS 2600)	Specialized Hydrogen Sulphide (TGS 825)
Baseline	0.69	1.06	0.71
Ammonia	1.16 ± 0.08	0.27 ± 0.01	1.15 ± 0.10
Hydrogen Sulphide	1.13 ± 0.02	2.19 ± 0.10	1.46 ± 0.07
Sulphur Dioxide	1.01 ± 0.02	1.67 ± 0.07	0.95 ± 0.06
Carbon Monoxide	1.82 ± 0.01	1.53 ± 0.04	2.06 ± 0.07
$NH_3 + H_2S$	1.22 ± 0.05	2.19 ± 0.10	1.43 ± 0.07
$NH_3 + SO_2$	1.19 ± 0.04	0.84 ± 0.04	0.95 ± 0.04
NH_3 + CO	1.82 ± 0.03	0.97 ± 0.01	2.14 ± 0.03
$H_2S + SO_2$	1.16 ± 0.03	2.15 ± 0.06	1.43 ± 0.04
H_2S + CO	1.76 ± 0.06	2.15 ± 0.08	2.11 ± 0.04
SO_2 + CO	1.88 ± 0.04	1.54 ± 0.06	2.02 ± 0.09
$NH_3+H_2S+SO_2$	1.96 ± 0.75	2.12 ± 0.03	1.58 ± 0.52
NH_3+H_2S+CO	1.69 ± 0.02	2.12 ± 0.03	2.09 ± 0.04
H_2S+SO_2+CO	1.69 ± 0.02	2.06 ± 0.05	2.13 ± 0.05

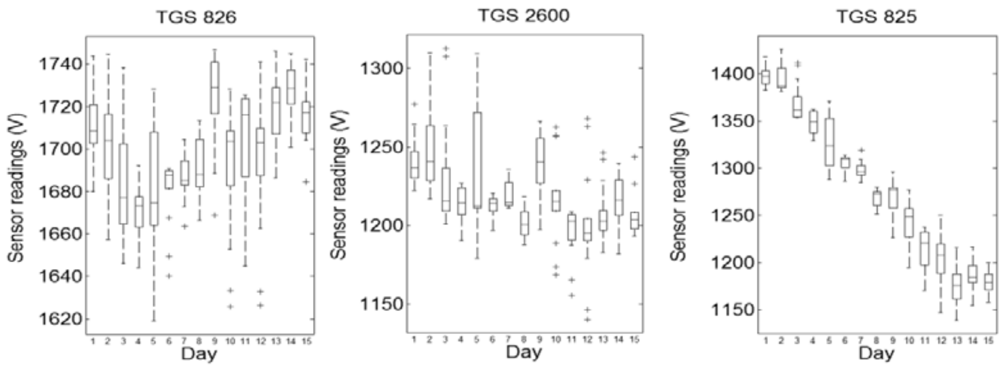


Figure 8: Distribution of three gas sensors data over the period of 15 days

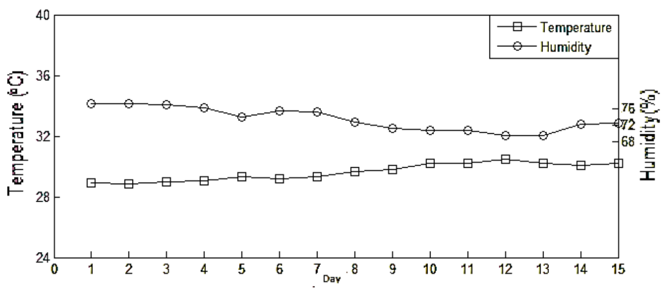


Figure 9: Temperature and humidity trends over the period of 15 days

6. Conclusions

The deployed system has performed as planned. Gas concentrations and trends in the swiftlet house are monitored and measured. It was also found that the microclimate of the target area provides critical data in terms of explaining and verifying data trends.

The microclimate data proves that the swiftlet house is well insulated and cloistered, where weather changes does not affect indoor climate. Gas concentrations were also recorded to be fluctuating for the duration of the study although at the time of writing, exact concentrations cannot be confirmed due to the effects of masking, unison, and inhibition of gases on sensors. The research team plans on using gas chromatography and mass spectrometry to validate the data. Also, more gas sensor nodes with more gas sensor types will be deployed to detect gas concentration levels within a room; to validate the dynamics of the gas in an enclosed area.

The concentration levels recorded have not yet exceed the Malaysian Standard for Industry Code of Practice on Indoor Air Quality 2010 by Department of Occupational Safety and Health (JKKP DP(S) 127/379/4-39). However, this standard may not apply to the swiftlet industry. Consequently, we propose that more research on the suitable gas levels in a swiftlet house to be done.

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