CHEMICAL ENGINEERING TRANSACTIONS

VOL. 30, 2012

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

Guest Editor: Renato Del Rosso

ISBN 978-88-95608-21-1; **ISSN** 1974-9791

DOI: 10.3303/CET1230010

Chicken Farm Malodour Monitoring Using Portable Electronic Nose System

Abu H. Abdullah*, Ali Y. M. Shakaff, Abdul H. Adom, Ammar Zakaria, Fathinul S.A. Saad, Latifah M. Kamarudin

Centre of Excellence Advanced Sensor Technology (CEASTech), Universiti Malaysia Perlis (UniMAP)
Taman Muhibbah, Jejawi, 01000 Kangar Perlis Malaysia
abu.hassan@unimap.edu.my

Malodour from the chicken farms is an issue that cause bitter relationships between local authorities and the public. The complaints cover the effects of malodour to the environment with a potential health threat to animals and humans. This research proposes a fundamental study of malodour mapping for the chicken farm using electronic nose (e-nose) system. The findings can be used to enable effective malodour detection, management and control. The system is also being used to monitor the malodour main chemical component i.e. ammonia, as an early indicator of the chicken health status. The malodour from the farms, temperature, humidity, wind speeds and directions are recorded. Artificial Neural Network (ANN) technique is used to predict the malodour index of each location to generate the malodour mapping of the area. Simulation results show that the system can be effectively used for malodour monitoring in the chicken farm.

1. Introduction

An unpleasant odour or malodour volatile organic compounds (VOCs) emits bad smell similar to pungent, rotten eggs and stinking garbage wastes. The malodour nuisance which increase the environmental pollutants is an issue particularly when the farm exists near residential areas. This issue has threatened the livestock and poultry industry due to reduced quality of life and health for human population (Kim et al., 2007). Schiffman et al. (1995) reported that malodour affects the psychological status of human population nearby in term of emotional stress, anger and physical symptoms. This has induced conflicts between farmers, local authorities and local residents. In 2006, a total number of 141 complaints were received by the Department of Environment (DOE) about the chicken, pig and slaughter houses in Malaysia (Othman et al., 2007).

The malodour emitted from the farm waste and chicken manure and carried on dust and other particles (Eby and Win, 1969). The emission and dispersion are influenced by the quantity, moisture, temperature, wind, season, time of day and distances to human population (Gronauer et al., 2003). Other factors include diet, activities, building structure, ventilation system and cleaning schedule (Leek et al., 2007). The barn temperature and humidity are also important for chicken health. The suitable ranges are 26 - 29 °C for temperature and 50 – 70 % for humidity (Unit Unggas, 2006).

The gas chromatography coupled with mass-spectrometry (GC–MS) analysis is used to identify the malodour chemical components. The main component is ammonia (NH_3) and used as the '*quality marker*'. Others are methane (CH_4) and hydrogen sulfide (H_2S). The concentrations of other organic volatile compounds are weak and can be negligible (Mackie et al., 1998).

Please cite this article as: Abdullah A.H., Shakaff A.Y.M., Adom A.H., Zakaria A., Saad F.S.A. and Kamarudin L.M., 2012, Chicken farm malodour monitoring using portable electronic nose system, Chemical Engineering Transactions, 30, 55-60
DOI: 10.3303/CET1230010

The malodour chemical components are toxic and have the potential to be health hazard to the chicken and employees of these farms. The animals began to produce visible signs of intoxication when they were exposed to ammonia levels higher than 20 part per million (PPM) for more than 6 weeks (Andersen et al., 1964).

The impact of malodour concentration to the neighbourhood area is also an important aspect to be considered in this issue. Five factors have been identified related to malodour impact, and they are frequency, intensity, duration, offensive and receptor (Sheridan, 2002). Most countries such as Malaysia through DOE have developed regulations for malodour control. The regulation was used to develop an effective malodour control system. An identification and quantification technique may be beneficial to monitor malodour impact on humans, chicken and the farm environment.

The malodour mapping could be used to monitor the dispersion impact on the farm area, calculate setback distance to local population and estimate the maximum emission permitted from the facilities (Hayes et al., 2006). It can also be used as a guideline to solve the disputes between farmers and local people and monitor the violations of environmental issues to support the control regulation.

This paper proposes a monitoring system that automatically and continuously tests malodour and metrological sample data using portable Electronic Nose (e-nose). The system monitors, records and analyse acquired data from various locations of the farm in real-time. The acquired data can be used as an early indication of the chicken health status by monitoring the main chemical components of chicken farm malodour, i.e. ammonia (NH_3), in the barns.

The sensor responses can be used as an early indicator of the chicken health status. The sensors data are analysed using multivariate statistical analysis and Artificial Neural Network (ANN) techniques. Multivariate statistical analysis; i.e. Principal Component Analysis (PCA), Hierarchical Cluster Analysis (HCA) and Linear Discriminate Analysis (LDA), are used to discriminate the malodour samples from various location of the farm. Based on the analysis, the malodour concentration index of each location is predicted using the ANN. The index will be used to generate malodour mapping of the farm area. The e-nose is connected to a web-based system that provides the ability to remotely monitor its main chemical components and malodour mapping in real-time.

2. System Description

The e-nose is a low power portable system consists of chamber, sensing unit, embedded controller and software for system operation. The headspace sampling chamber was developed for the sensors array. Teflon was selected as the chamber material because of its odourless and inert characteristic to minimize the sample memory effect (Abdullah et al., 2011). The e-nose uses an array of selected Metal-Oxide Semiconductor (MOS) sensors from Figaro Engineering with vary sensitivity and selectivity to the sample. The sensors responses profiles are called '*fingerprints'* corresponds to the sample. A SHT75 sensor from Sensirion Technology was used to measure the environment temperature and humidity. A dsPIC33 microcontroller from Microchip Inc. was selected as the embedded controller for the e-nose.

The system consists of wireless e-nose nodes for data acquisition module around the farm area. A two dimension anemometer from Gill Instruments was connected to a notebook to measure air speed and direction. The e-nose was connected using XBee wireless module to the notebook as the base station. The module miniature size, low cost and low power make it ideal for the isolated location around the farm (MaxStream, 2006).

A web-based programme was developed for data transferring from notebook to the web server in real-time via Transmission Control Protocol/Internet Protocol (TCP/IP). The customized Graphical User Interface (GUI) for data acquisition and database was developed using Visual Basic version 6.0 software. The acquired malodour data are used to train the ANN model off-line using MATLAB toolbox (version 7.7, Mathworks) software. The process used Multi-Layer Perceptron (MLP) method and *Levenberg-Marquardt* (LM) algorithm. The generated ANN model was uploaded onto the e-nose microcontroller memory. The e-nose was used to collect sample data at various locations in real-time, process and predict the concentration index using the embedded ANN model. The web-based system will display real-time malodour dispersion mapping around the farm based on the sample concentration index at each location.

3. Methodology

3.1 Sampling Technique

The sample data were collected in April and May 2011 at a chicken farm which is 3 km away from residential areas. The samplings were conducted on the 8th, 15th, 22nd, 29th and 36th days of the chicken 40-day breeding period. This process was repeated at the same time and in same climate conditions to check for reproducible and repeatability. During the sampling process, two e-noses were linked wirelessly with a notebook as the base station. An anemometer was also connected to the notebook as shown in Figure 1. The samplings were conducted on-site in the chicken barns and the surrounding areas. Each e-nose was used to acquire data at three different locations as illustrate in Figure 2. (E-nose one for location A, location B and location C. E-nose two for location D, location E and location F).

The sampling process used traps and purge technique. For the "*Purge Cycle*", ambient air was supplied to the chamber inlet to "*clean*" the sensors. After the completion of the "*Purge Cycle*", the system will be set to idle state to enable the sensors to return to their baseline values. The "*Sniff Cycle*" follows, and the malodour sample was supplied to the sensors array through the chamber inlet. Then the e-nose was set to idle state to enable the sensor responses to reach their steady state values before the data being recorded and analysed. After that, the e-nose underwent purging stage again for the sensors responses return to the baseline values. The system also measures the environmental parameters such as temperature, humidity, wind speed and direction.

Figure1: The e-nose sampling system.

Figure 2: The sampling locations of the farm.

3.2 Data Processing

3.2.1 Multivariate Analysis

Hierarchical Cluster analysis (HCA) was used to process the data. This technique classifies the data into specific vectors cluster groups based on the similarity between data vectors. This technique uses Euclidean Distance to calculate the distance of each individual component for clustering. The grouping starts by a process of agglomeration division and gradually merged close groups in a single group as shown by dendrogram plot (Scott et al., 2007). Principal Components Analysis (PCA) was also used for clustering the multi correlated data according to groups. The objective is to find hidden relationships among the unknown data variables. This technique reduces the size of data without losing any important information (Jolliffe, 2002). It compares sample malodour qualitatively by showing the result of group cluster.

3.2.2 Artificial Neural Network (ANN)

The measured data was normalised to filter-out outliers and dominant measurements that will affect the system performance. The ANN model was trained off-line on a notebook using MATLAB software. The ANN utilises Multi-Layer Perceptron (MLP) toolbox with Levenberg-Marquardt (LM) algorithm. Sixty percent of the data was used for the ANN training, and the rest was used for validation. The initial weights for the ANN were selected randomly using the '*Nguyen–Widrow'* algorithm. The training uses iterative weight update approach and the network being validated after each epoch. The model uses the hyperbolic tangent function at the hidden and sigmoid function at the output to enable the ANN result ranging from zero to one. The network model was validated by testing it using the remaining 40 percent of the data. The network model is obtained at the end of the training if the target mean square error (MSE) value is achieved. The generated model variables were attached as an include file in the microcontroller program and was uploaded into memory during compilation.

4. Results and Discussion

The acquired data was used to monitor chicken health conditions based on the main malodour volatile components inside the barn. Figure 3 illustrates ammonia sensor response during the chicken breeding period (week1 to week 5). The measured data varied slightly but it is acceptable because it is still within the 'acceptable range'. The system monitors the sensor response and generates a pattern of malodour data. An unusual pattern of the data is an early indication of chicken poor health condition. The system will automatically alert the management via internet for appropriate immediate action.

The multivariate statistical data analysis was used to assess the linear separability of the system measured data. The HCA was performed and dendrogram plot result is shown in Figure 4. From the plot, the malodour sample can be clustered into three different grouping based on the location; A and B at the front of the barn, C and D at the back, E at the right-side of the barn and F inside the barn. This plot proved the capability of the e-nose to differentiate the concentration of malodour at various location in the farm.

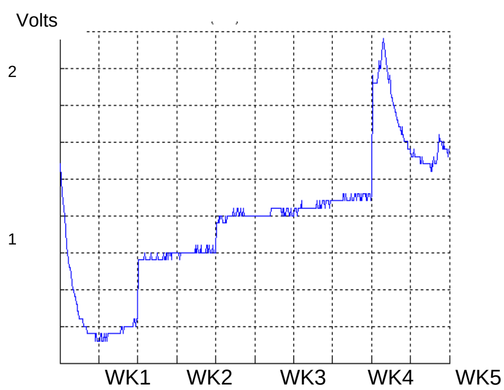

Figure 3: The Ammonia data measurement

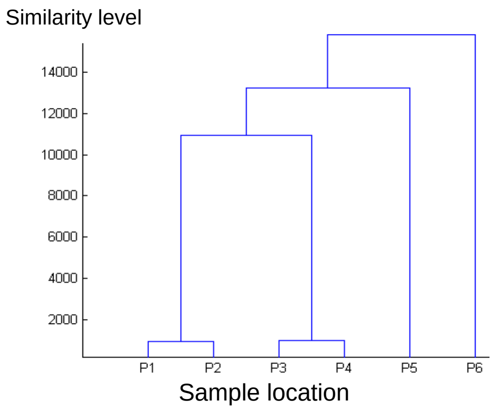

Figure 4 : The HCA plot

The PCA plot for the malodour is shown in Figure 5. The two-dimensional PCA plot is used because the first two PCs value are more than 90 % of the total variances (PC1 is 52.59 % and PC2 is 34.71 %). From the plot shown, the malodour sample can be clustered into three different groups; in which three locations (A, B and C) have low concentration, two locations (D and E) have moderate concentration and one location (F) has high concentration of the malodour.

The samples LDA results are better separated compared to PCA. The technique was used to improve the separation between groups of observations by rotating PCA components such that a maximum separation among classes is obtained. The LDA achieves 100 % correct classifications in both original grouped cases and cross-validated grouped cases as shown in Table 1. All of the multivariate statistical data analysis results show that the collected data can be used to train the embedded ANN model to predict the malodour concentration regarding to their location around the farm.

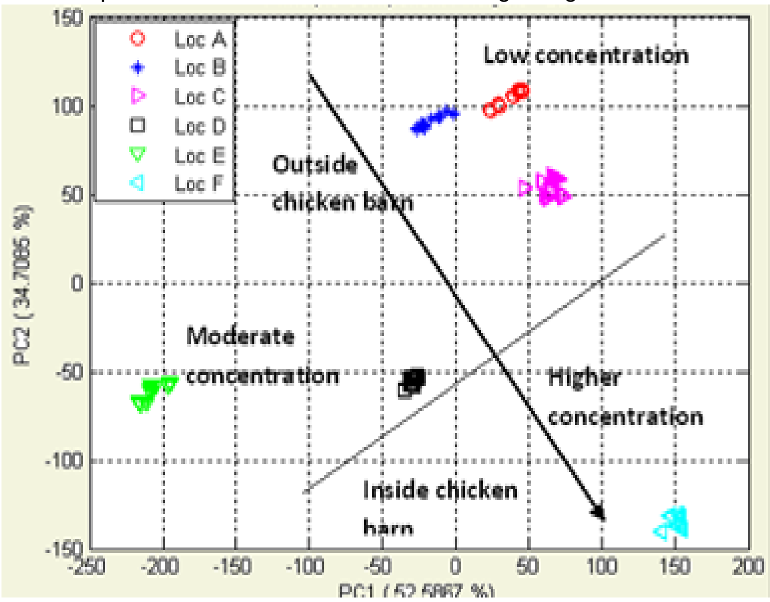

Figure 5: The PCA plot

Table 1: LDA classification results

Chicken age (days)	Group classified (%)	Cross validated classified (%)
8th	100	100
15th	100	100
22nd	100	100
29th	100	100
36th	100	100

Table 2: Malodour concentration index

Loc.	Chicken age (days)					Ave
	8th	15th	22nd	29th	36th	
A	0.28	0.34	0.34	0.36	0.37	0.34
B	0.32	0.35	0.38	0.37	0.38	0.36
C	0.40	0.43	0.45	0.45	0.45	0.44
D	0.60	0.63	0.63	0.63	0.65	0.63
E	0.62	0.64	0.67	0.67	0.67	0.65
F	0.72	0.73	0.75	0.80	0.83	0.77

The ANN classification results that predict the malodour concentration index at various locations were summarized and shown in Table 2. The malodour concentration index increase with the age of the chicken (highest malodour index is on the 36th day). This is because of the increase amount of pallets consumed by the chicken. It was also observed that as the malodour concentration index inside the chicken barn (location F) is the highest and followed by location E, D, C, B and A.

The ANN mapping index results have shown high correlation with the HCA, PCA and LDA results. This shows that the system was able to provide reliable malodour mapping of the farm area. This would allow an effective web-based malodour monitoring system to provide real-time information.

4. Conclusions

A malodour mapping for chicken farm utilising a portable e-nose system has been successfully developed. The system was able to acquired reliable and stable measured data for various locations in the farm based on their unique '*fingerprints*'. The HCA dendrogram plot and PCA plot proved the capability of the system to differentiate the concentration of malodour at different point location. The LDA achieves 100 % correct classifications indicate that the system is able to function accordingly. The system monitors the malodour main chemical component i.e. ammonia which can be used as an early indicator for the chicken health status. The ANN classification technique results show that the system is able to predict the malodour concentration index in the farm correctly. This shows that the system can be used to generate malodour mapping of a chicken farm. The mapping can be used as a guideline by the local enforcement agencies to enable effective malodour monitoring and control. Further work includes attaching pre-concentrators at the front-end of the e-nose and improves the sampling technique to increase the detection limit capabilities. The e-nose performance also can be improved by using specific sensors based on the applications or identified "*quality-markers*".

Acknowledgment

This project is partly funded by the Malaysian Ministry of Higher Education under the Prototype Development Research Grant Scheme (PRGS). A.H. Abdullah gratefully acknowledges the leave granted by Universiti Malaysia Perlis (UniMAP) to allow him to pursue his Ph.D.

References

Abdullah A.H., Adom A.H., Md. Shakaff A.Y., Ahmad M.N., Saad M.A., Tan E.S., Fikri N.A., Markom M.A., Zakaria A., 2011, Electronic Nose System for Ganoderma Detection, Sensor Letters, 9, 1–6.

Andersen D.P., Beard C.W., Hanson R.P., 1964. The Adverse Effects of Ammonia on Chickens Including Resistance to Infection With Newcastle Disease Virus. Avian Dis., 8: 369--379.

Eby H.J., Win G.B.,1969, Poultry House Dust, Odour and Their Mechanical Removal. Agricultural Waste Management Proceedings, Cornell University Conference on Agricultural Waste Management, Syracuse, NY, 303-309.

Gronauer G., Neser S., Maier B., 2003, Monitoring Of Odor Emissions From Different Pig Housing Systems With Chemical Sensor Array, Proceedings of Air Pollution from Agricultural Operations III Conference, 17–25.

Hayes E.T., Curran T.P., Dodd V.A., 2006, A Dispersion Modelling Approach to Determine The Odour Impact of Intensive Poultry Production Units in Ireland, Bioresource Tech. 97, 1773–1779.

Jolliffe I.T.,2002, Principal Component Analysis, 2nd ed. Springer-Verlag, USA.

Kim K.Y., Ko H.J., Kim H.T., Kim Y.S., Roh Y.M., Lee C.M, Kim H.S., Kim C.N., 2007, Sulfuric Odorous Compounds Emitted From Pig-Feeding Op., Atmospheric Environment:41, 4811-4818,

Leek A.B.G., Hayes E.T., Curran T.P., Callan J.J., Beattie V.E., Dodd V.A., O'Doherty J.V., 2007, The Influence Of Manure Composition On Emissions Of Odour And Ammonia From Finishing Pigs Fed Different Concentrations Of Dietary Crude Protein, Bioresource Tech., 98, 3431–3439.

Mackie R.I., Stroot P.G., Varel V.H., 1998, Biochemical Identification And Biological Origin Of Key Odor Components In Livestock Waste, Journal of Animal Science, 76, 1331–1342.

MaxStream, 2006, XBee/XBee-PRO 802.15.4 OEM RF Module, <www.libelium.com>, Accessed 19.07.2012.

Othman M.N., Yunus M.N.M., Dahlan K.ZM., Zakaria N., Hamid K.H.K., 2007, Development of Odour Monitoring and Control in Malaysia, <www.aidic.it/nose2008/webpapers/2Othman.pdf>, Accessed 19.07.2012.

Schiffman S.S., Sattely E.A., Miller E.A, Suggs M.S., Graham B.G., 1995, The Effect Of Environmental Odors Emanating From Commercial Swine Operations On The Mood Of Nearby Residents, Brain Res. Bull., 37, 369-375.

Scott S.M.; James D., Ali Z., 2007, Review: Data Analysis for Electronic Nose Systems, Microchim. Acta., 156, 183–207.

Sheridan B.A., 2002. Biofiltration and Atmospheric Dispersion of Gaseous Emissions From Pig Production Units. Ph.d. Thesis, University College Dublin, Ireland.

Unit Unggas, 2006, Broiler Chicken Farming Guidelines, Veterinary Services, Ministry of Agriculture, (in Malaysian) Putrajaya, Malaysia.