Development of a Novel Electronic Nose Assembly for the Detection and Deletion of Fungi in North-East Region of India

Subhash C. Arya , Anurag Agarwal , Dileep Kumar and Jean Simon Kharkongor
Department of Electronics and Communication Engineering, School of Technology,
North-Eastern Hill University Shillong -7930022, Meghalaya, India

ABSTRACT

This paper reports about design and development of a novel mobile electronic nose assembly, which is an inspection cum controlling system. It is used to detect and control the fungi growth. The Model is tested in North-Eastern (Shillong) Region of India. The diseases like *Aspergillosis, mucor amphibiorum, penicillium marneffe*i and *hypersensitivity pneumonic* are caused due to long term exposure of *Aspergillus Sp., Mucor Sp.* and *Penicillum Sp.* fungi which causes severe breathing problem, bleeding lungs, cancer and even death . The developed system can be used in the room/laboratory/library or any closed environment in which the fungal growth control is needed to prevent the spread of fatal diseases.

General Terms

Design, gas sensor, fungi elimination

Keywords

Artificial olfaction, fungal growth, health, Electronic Nose.

1. INTRODUCTION

In Shillong, Meghalaya, India, rain begins in the month of April and continues till the end of the month of July. During this period, it receives an average rainfall of 2163 mm. Along with rainfall the temperature varies between 14ºC and 24ºC [1]. Hence, these moderate conditions provide excellent breeding environment for fungi, both harmful as well as useful.

Residing in a fungal environment can be fatal in extreme cases and even a short term exposure to such conditions is highly injurious to human respiratory system. Dieses like *asphergillosis* and *hitoplasma* are caused due to long term exposure of various fungi in particular by *crypococcosis* and *blastomycosis which causes severe breathing problems* [2]. Short periods of exposure to lower levels of *mold* may include the common symptoms of sneezing, skin irritation, itchy, watery eyes and headaches. People are also suffered by runny nose, nasal congestion, coughing, postnasal drip, swollen eyes, dark circles, crusty eyes, itchy nose and itchy throat. Long term exposure results *aspergillus* which can lead to skin rashes, hair loss, abdominal pain, tinnitus, hearing loss, long-term memory loss, bleeding lungs, cancer and even death [3].

The growth of fungus depends on temperature, humidity and light intensity [4]. Temperature and humidity can efficiently be controlled by air-conditioners readily available in the markets. However, due to poor cleaning practices of the appliances in long period, the air-conditioner filter provides hospitable conditions for fungal growth upon them. Hence, the preventer become a fungus spreader.

There is no readily available solution for detection and deletion of fungi in a single integrated system particularly in Shillong. Presently, available techniques require direct human contact with the fungi for eradication. There is no system that is designed for specific fungus detection in the North-Eastern region of India encountered in rainy season.

We proposed and developed a novel electronic nose assembly, which is an inspection cum controlling system used to detect and control the fungi growth. The system can be used in the room/laboratory/library/any closed environment in which the fugal growth control is needed.

The research in field of electronic nose technology has been carried out since late 1982 [5-8]. The electronic nose functions to imitate odors and flavors similar to human nose. The human system works in a systematic manner following specific procedures to identify, compare, quantify and other applications. The imitation cannot be perfected since the olfaction is prerogative of every individual. Recently, electronic nose finds potential application in the field of winery, bakery, tea and agriculture [9-13].
A considerable work has been done in study of fungi diversity in North-Eastern India. These include work in the classification of fungi on the basis of their symbiotic relationship with other plants [14].

Also, there are some fungi (*Aspergillius elegans, A. humicola, A. ustus, A. wentii, A. candidus, A. tamccrii and A. japonicus*) which remain dormant for the major part of the year [15].

2 EXPERIMENTAL

2.1 Design of Mobile Electronic Nose

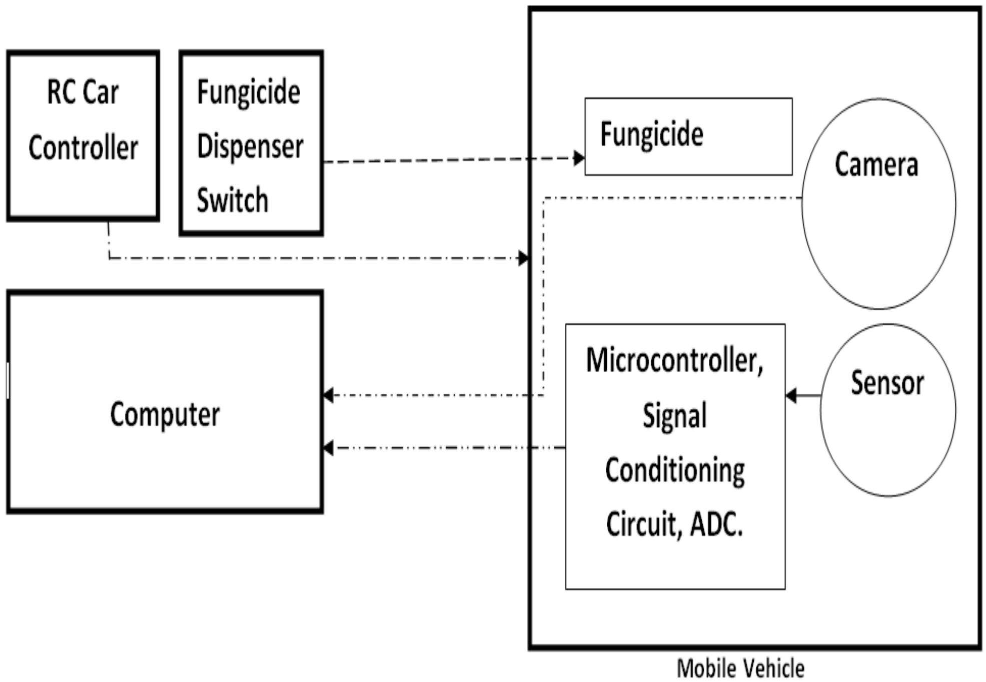


Figure 1. Block diagram of designed mobile Electronic Nose

The block diagram shown in Figure 1 consists of a mobile vehicle, gas sensor, fungicide dispenser, wireless camera, microcontroller, and computer.

Fungicide Dispenser:

A broad spectrum fungicide has been used to eradicate the detected fungi. The fungicide has been filled in compressed form in a can for spraying on fungi. A mechanical system is designed that triggers fungicide's spray remotely (wireless).

Wireless CMOS Camera:

The camera gives the freedom to the user to stay out of the infested area. It has 100 m range and works at 24 GHz frequency. The images or videos of site are viewed on computer to take the decision.

Microcontroller:

The 8051 microcontroller help the gas sensors to send the desired signals to the computer wirelessly. The sensors send the output to the signal conditioning circuit followed by ADC.

Mobile Vehicle:

The CMOS camera, fungicide dispenser, gas sensors unit are mounted on commercially available remote control car which works at 27 MHz frequency. This vehicle works on basis of RF (Radio wave frequency) module with paired transmitter and receiver. An IR (Infra-Red frequency) module was also available but with poor range of about 6 inches and line of sight control only. The RF circuitry gives the freedom to operate at long distances (at up to 30 metres) and is more efficient even if obstacles are present between the transmitter and receiver hence overcoming the line-of-sight operation drawback.

2.2 Data Acquisition

The fungi sample was obtained upon a substrate in a petri dish. This experimental was put in a closed room for 24 hours under the room temperature from 24 to 16 ^{0}C. After 24 hours, sample was sent for laboratory testing. The image of fungal growth is shown in Figure 2. The gas sensor TGS 822 interface was put in the same room along with the petri dish to estimate the gas levels [16]. The sensor is commercially available from Figaro Company, Japan.

The fan in front of sensor extracts air and blows the detected gas on sensor surface. Based on the software algorithm an electrochemical reaction, the sensor function identifies the fungi. The circuit diagram of sensor consist mainly of load resistance (R_L) which serves multiple purposes of obtaining output and regulating sensor power consumption as shown in Figure 3a.

All the R_L are finally connected to signal conditioning circuit consisting of amplifiers and filters.

The sensor TGS 822 has been used since a long time and presently its successor TGS 2620 is found to be of same capability with added features. This new sensor manufactured by same company has reduced number of pins from 6 in TGS 822 to 4 in TGS 2620. This reduces the complexity in the interfacing circuitry. Moreover, the power consumption i.e., circuit voltage has reduced by over 50% making it more efficient. The reduction in sensor size and pins helps mounting on the vehicle easier.

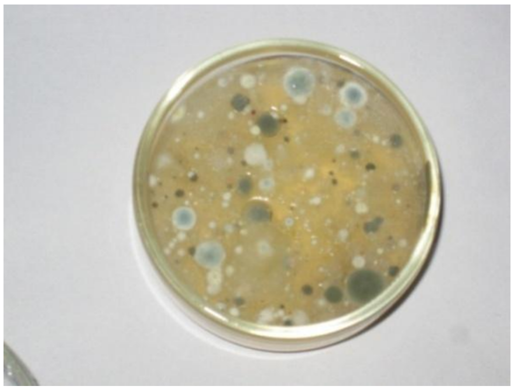
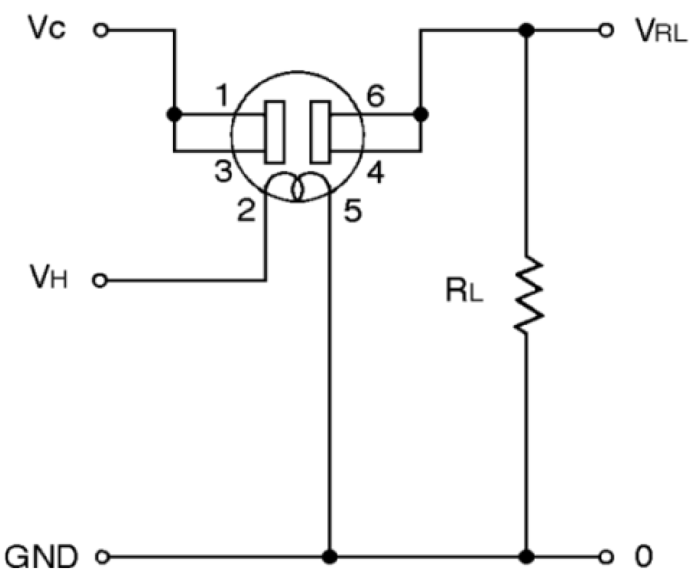


Figure 2. Image of fungal growth (*Aspergillus Sp*., *Penicillium Sp.and Mucor Sp*.) in Lab. Of NEHU, Shillong

On TGS 2620 the sensing element is comprised of a metal oxide semiconductor layer formed on an alumina substrate of a sensing chip together with an integrated heater. The circuit in the Figure 3b is completed with connection of a variable resistance-pot to control the level of the gas detected.

A simple electrical circuit converts the change in conductivity to an output signal wh Sensor nds to the gas concentration. This consists of a compa... ...icator.

Figure 3a. Internal circuit of Sensor TGS 822 (© Figaro,



Japan)

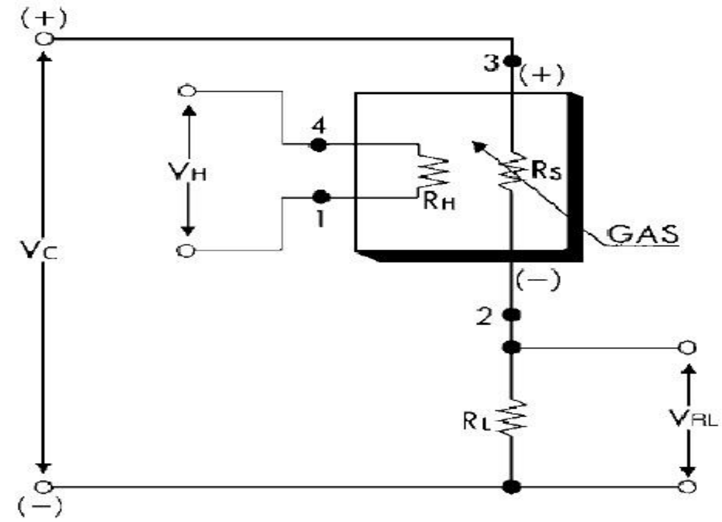


Figure 3b. Measuring circuit of Sensor TGS 2620 (© Figaro, Japan)

The output is connected to a signal conditioning circuit followed by ADC (Analog to Digital Convertor) and finally this is fed to the microcontroller which triggers the next stage of the deletion process.

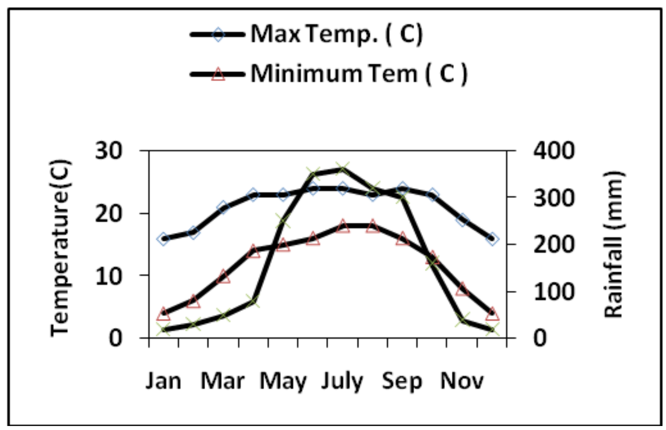
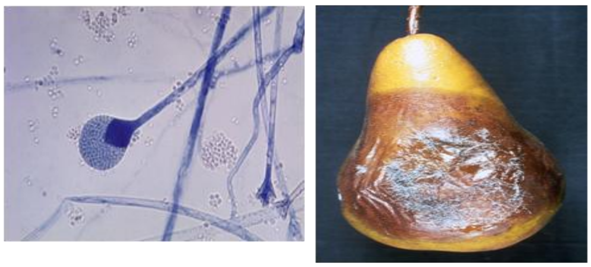


Figure 4. Maximum, Minimum Temperature (^{0}C) and rainfall (mm) variation with respect to per month in Shillong, Meghalaya, India from 1903 to 1999. (Source: Ref. [1])

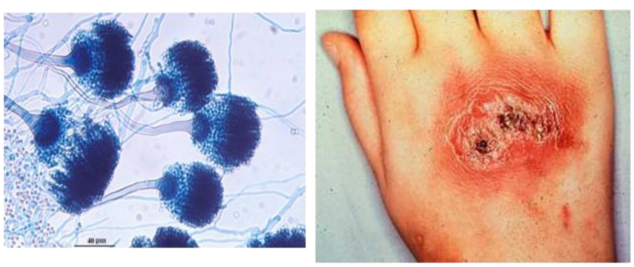
As shown in the Figure 4, the temperature varies from 14 ^{0}C to 24^{0}C in months of April-July which are considered as summer in Shillong. Months of November to February have temperature range from 4 ^{0}C to 21 ^{0}C and are winter. June is the hottest and January is the coldest. The annual rainfall is 2163 mm with highest in the month of June of 350 mm [1]. These environmental conditions are best suited to grow very fatal fungi.

The microscopic view of *Mucor Sp*., *Penicillium Sp*., and *Aspergillus Sp.* are shown in Figure 5 (a-c) respectively. The diseases like *Aspergillosis* [17-19], *mucor amphibiorum* [20-21], *penicillium marneffe*i [22-23] and hypersensitivity pneumonic are caused due to long term exposure of *Aspergillus Sp., Mucor Sp.* and *Penicillum Sp.* fungi.



(a): *Mucor Sp.* and its effect on pear

(b): *Penicillium Sp.* and its effect shown on human face



(c): *Aspergillus Sp*. and its effect shown on human hand

Figure 5. Microscopic view of fungi and its affect

For the purpose of data computation, the computer is installed with the software Matlab R2009a which is used for the detection of fungi after image processing. The software comes with several toolboxes which are efficient in determining the presence of dark spots in an image. The dark spots here are fungi colonies provided having a single colored background.

3. RESULT AND DISCUSSIONS

3.1 Data Interpretation:

The experimental was tested in the advance Biotechnology laboratory, of NEHU, Shillong. The following fungi species were found in abundance on the substrate: *Aspergillus Sp., Penicillium Sp., Mucor Sp.* The further study on these fungi and their environment ill effect were studied from literature. Some ill effects have been shown in Figure 5. This gave better understanding on the behavior, characteristics and effect of fungi common in Shillong, the North-Eastern part of India. The fungicide was thus selected and pressurized into a can to eliminate the fungi.

3.2 Computer Programming:

The wireless camera captures the image and sends them to computer. The computer is installed with the Matlab R2009a. The images are operated with functions of color segmentation, simplification and then edge enhancement. The aim is to identify the fungi in the form of circular spots in a uniform background image. The Matlab software comes with various inbuilt toolboxes for image processing. The Matlab program first converts the original RGB (Red Green Blue) image in to gray scale image followed by color enhancement. The result is shown in the figure 6a. A histogram is also available for a theoretical review of the image as shown in the Figure 6b.

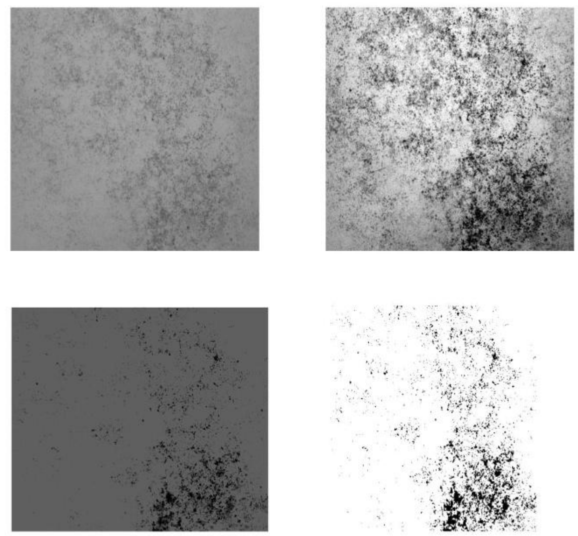


Figure 6a. Images of steps taken using the image processing software.

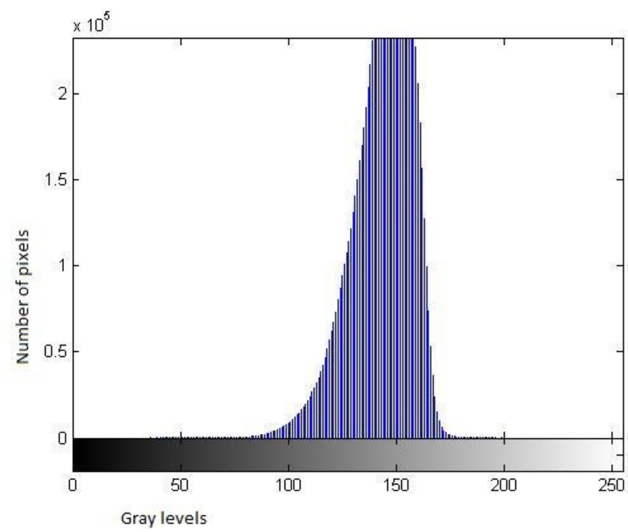


Figure 6b. Image of resulting histogram.

3.3 Functionalities:

The image of developed mobile electronic nose with computer and remote control setup is shown in Figure 7.

Along with the primary objective of fungi detection, some other prominent functions are also done by this assembly. For visual assistance of the user sitting at the remote and safe surrounding, the vehicle uses a wireless CMOS camera. This camera gives high resolution videos at 20 fps and with resolution of 600 x 900 pixels. The spray gives a modest range of 1.5 feet from its nozzle up to the target. Though, the vehicle gives a wide area of movements i.e. forward, backward, left and right directions, but the fungicides spray is limited in forward direction. Hence, the operator of the vehicle needs to be trained in handling its movement from remote.

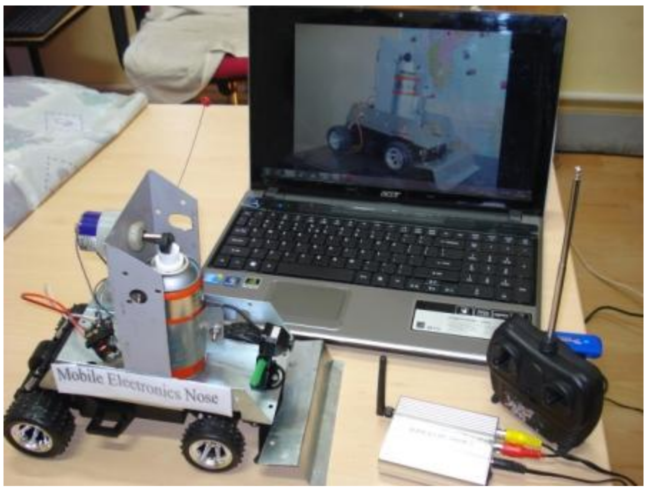


Figure 7. Image of developed mobile Electronic-Nose with computer and remote control setup in NEHU Shillong, India.

Once the fungicide has been spread, it was found necessary to remove the debris. This was achieved with a mechanical setup for cleaning the path of the RC vehicle by close surface contact. Also a small suction pump was used to suck in the dry fungus and other surface particle.

Since the spray is not currently free to move, we need to increase its degree of freedom to be elevated and moved left and right. The image obtained can be further worked with algorithm to give the nose capability of image processing and pattern recognition. The advancement in nanotechnology and VLSI can give more advance sensors required for rapid and more accurate detection.

4. CONCULSIONS

A novel mobile Electronic Nose is designed and developed with features of detecting the most commonly fungi i.e. *Aspergillus Sp., Penicillium Sp. and Mucor Sp.* were found in closed environment of Shillong. The developed mobile Electronic Nose is remotely controlled and has facility to kill the harmful fungi present on the surface of wooden tables and workbenches. Hence, it plays a great role to clean the workplace environment and preventing the spread of fatal diseases like *mucor amphibiorum*, *penicillium marneffei*, hypersensitivity phenumonics and *asphergillosis*. Therefore, the mobile Electronic Nose will serve the human being if this prototype developed model is commercialized.

5. ACKNOWLEDGMENTS

Authors would like to thank to Dr. S. R. Joshi, Dept. of Biotechnology, NEHU, for his resource sharing and to Dr. L. J Singh HOD (ECE), Prof. S. Choudhury, Dean (SOT), NEHU, Shillong for encouragement of carrying out this work. We are also thankful to Varun Kumar and Smita Asthana for assistance.

6. REFERENCES

[1] Choudhary, V., and Bhattacharya A. 2002. Suitability of Pinus Kesiya in Shillong, Maghalaya for tree-ring analysis. *Current Science*, vol. 83, no.8, 1010-1015

[2] Bush R. K., Portnoy ,J. M. Saxon, A., Terr, A. I. Wood R. A.. 2006. The medical effects of mold exposure. *The Journal of Allergy and Clinical Immunology*, vol.117, no. 2, 326-333.

[3] http://www.ehow.com/about_5414539_symptoms-mold.html

[4] www.wikipedia.com/fungus

[5] Persaud K.C. and Dodd, G. 1982. Analysis of discrimination mechanisms in the mammalian olfactory system using a model nose. *Nature*, vol. 299, 352-355, 1982 doi:10.1038/299352a0

[6] Canhoto O., Pinzari F., Fanelli C., and Magan N. 2004. Application of electronic nose technology for the detection of fungal contamination in library paper. *In. Biodeterioration & Biodegradation*, vol. 54, 303-309

[7] Röck F., Barsan N., and Weimar U. 2008. Electronic Nose: Current Status and Future Trends. *Chem. Rev*., vol. 108, 705-725

[8] Wilson A. D. and Baietto M. 2009. Application and Advances in Electronic-Nose Technologies. *Sensors*, vol. 9, 5099-5148; doi: 10.3390/s90705099

[9] Dutta, R., Kashwan, K. R., Bhuyan, M., Hines, E. L., and Gardner, J. W. 2003. Electronic nose based tea quality standardization. *Neural Networks*, vol. 16, 847-853

[10] Gómez, A. H., Wang J., Hu, G., and Pereira, A. G. 2006. Electronic nose technique potential monitoring mandarin maturity. *Sensors and Actuators B*, vol. 113, 347-253

[11] Mańn, S., Vinaixa, M., Brezmes, J., Llobet, E., Vilanova, X., Correig, X., Ramos, A. J., and Sanchis, V. 2007. Use a MS-electronic nose for prediction of early fungal spoilage of bakery products. *Int. J. Of Food Microbiology*, vol. 114, 10-16

[12] Gómez, A. H., Hu, G., Wang J., and Pereira, A. G. 2006. Evaluation of tomato maturity by electronic nose. *Computers and Electronics in Agriculture*, vol. 54, 44-52

[13] Paolesse, R., Alimeli, A., Martinelli, E., Natale C. D., D'Amico, A., D'Egidio G. M., Aureli, G., Ricelli, A., and Fanelli C. 2006. Detection of fungal contamination of cereal grain samples by an electronic nose. *Sensors and Actuators B*, vol. 119, 425-430

[14] Markom, M.A., Shakaff, A.Y., Adom, A.H., Ahmad, M.N., Abdullah, A.H.. Fabrication of a Hand-held Electronic Nose http://dspace.unimap.edu.my/dspace/bitstream/123456789/7438/1/Fabrication%20of%20a%20Hand-held%20Electronic%20Nose.pdf

[15] Agarwal,, C.P. 1977. Fungal Degradation of Cellulosic Materials in Assam, I. Studies On Soil Aspergillei. *Def. Sci. J.*, vol.27, 167-170

[16] Figaro Gas Sensor,(1992). Technical Reference, http://www.figaro.com, (July 2006)

[17] Garbino, J. 2004. Aspergillosi *Orphanet Encyclopedia*, August 2004, 1-7,

[18] Lapham, M. E. 1926. Aspergillosis of the Lungs and its Association with Tuberculosis. *Jn. of American Medical Association*, vol. 87, no. 13, Sept. 25, 1926, 1031-1033

[19] Pitt, J. I. 1994. The current role of Aspergillus and Penicillium in human and animal health. *Journal of Medical and Veterinary Mycology* 1994. 32, Supplement 1, 17-32

[20] Dizbay M., Adisen E., Kustimur S., Sari N., Cengiz B., Yalcin B., Kalkanci A., Gonul I. I. and Sugita T. 2009 . Fungemia and Cutaneous Zygomycosis Due to Mucor Circinelloides in an Intensive Care Unit Patient: Case Report and Review of Literature. *Jpn. J. Infect. Dis*, vol. 62, 146-148

[21] Chauhan, H.V. S. and Roy, S. , *Poultry Diseases, Diagnosis and Treatment* , 3rd Edition, New Age International Publisher, 2007

[22] Vanittanakom, N., Fisher, M. C., and Sirisanthana, T. 2006. Penicillium marneffei Infection and Recent Advances in the Epidemiology and Molecular Biology Aspects Clinical *Microbiology Reviews*, vol. 19, no. 1, Jan. 2006, p. 95–110

[23] Alexander H. W van Assendelft, Raitio M., and Turkia, V. 1985. Fuel Chip-Induced Hypersensitivity Pneumonitis Caused by Penicillium Species, *Chest, journal of the American College of Chest Physicians.* Chest 1985; 87; 394-396, DOI 10.1378/chest.87.3.394