CHEMICAL ENGINEERING TRANSACTIONS, Volume 15, 2008
Edited by Renato Del Rosso

The air quality monitoring of the Closed Environment: a long term space mission scenario

E. Martinelli[1], E. Zampetti[2], S. Pantalei[2], M. Santonico[1], G. Pennazza[1], R. Paolesse[1], G. Mascetti[3], V. Cotronei[3], C. Di Natale[1] and A. D'Amico[1]

[1]Department of Electronic Engineering, University of Rome Tor Vergata, Via del Politecnico 1, 00133, Rome, Italy
[2]CNR-IMM, Via del Fosso del Cavaliere, 00133 Rome, Italy.
[3] Italian Space Agency, viale Liegi 26, 00198 Rome, Italy

The realiziability of the long-term manned space missions requires the development of a system to a continuous monitoring of the air quality inside the spacecraft. For this scope, among different solutions, the artificial olfactory system has been considered. In the context of an ESA-MAP project, an electronic nose specifically designed for air quality control in closed environment is under development. After several ground experiments concerning the monitoring of biofilter efficiency, the instrument has been tested during the ENEIDE mission on board the International Space Station. The paper shows, a short resume of the results obtained in the two cases.

1. Introduction

In the long-term manned space mission one of the most important point is the control of air quality inside spacecrafts. For this reason, there is a high demand of self-sustained depuration systems combined with air quality monitoring. This is a typical situation where an array of non-selective chemical sensors may be efficiently applied by various space agencies [1,2].

More recently, electronic noses were considered for more specific tasks such as for instance the efficiency control of the depuration systems of the chemicals emitted by animals and plants. , ESA promoted a MAP project aimed at developing biofilters to remove chemicals from animal cages and from bioreactors the Micro-Ecological Life Support System Alternative (MELISSA) developed by ESA [3]. An overview of the project can be found in the references 4 and 5.

In the next sections, the first part is dedicated to illustrate the results obtained in the framework of the ESA-MAP project and the second part will show the experience gained in the International Space Station during the ENEIDE mission where a space version of the instrument has been tested in order to verify the correct functioning.

2. Ground Experiment: the BAF project

The project goal was the development of an air filter in system operating in closed environments. The filter efficiency was controlled by an electronic nose based on an array of eight Quartz Micro-Balances (QMB) coated by films of Metalloporphyrins. QMBs are chemical sensors where the amount of mass absorbed in a sensitive film is translated into a change of frequency of an electric signal. Sensors connected to oscillator circuits are embedded in an instrument where the frequency shift is measured and data are sent to an external computer for successive analysis aimed at odor recognition and classification. In figure 1 a picture of the "ground version" of the instrument used for the project measurements is shown.

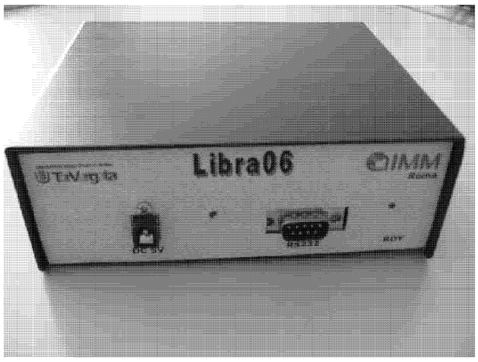

Figure 1 The Electronic Nose utilized in ground-based experiments

To verify the capability of the instrument to monitor the BAF efficiency, the enose has been tested in a set of experiments measuring the odour of air before and after biofilter units. As an example the results concerning MELISSA compartment I are herewith reported. In particular the experiments were aimed at exploring the capability of the instrument to recognize the occurrence of biofilter malfunctioning, for the scope different failure conditions were induced and measured. In the figure 2 a picture of the experimental set-up is represented. During the experimental sessions the temperature and relative humidity is held constant (T=20-24°C and RH=30-50%).

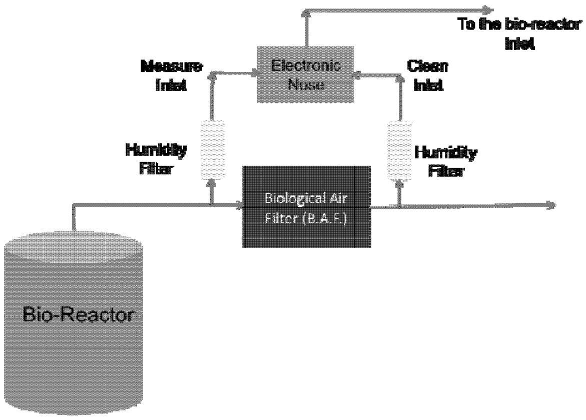

Figure 2: a sketch of the experimental set-up used for the electronic nose measurements.

Figure 3 shows the PLS-DA Scores Plot of the electronic nose measures of air samples related to a normal working state and in the case of two failure conditions. The enose measure related to the first failure condition have been collected after 5 hours of the failure inductions. This is reflected by the net difference compared with the normal condition. The second failure condition has been applied to the biofilter during the measurement session. The red arrow put in evidence the time evolution of the electronic nose responses that start to move in the "failure condition zone". It is also important to remark in the first failure condition a time evolution of the enose responses that is correlated with a decreasing of a filter efficiency. Moreover, the interesting results has been also confirmed considering that the samples with the "◊" and "*" as label have been applied as test samples. Details of the experiments with MELISSA bioreactor and animal cages are reported in references 6 and 7.

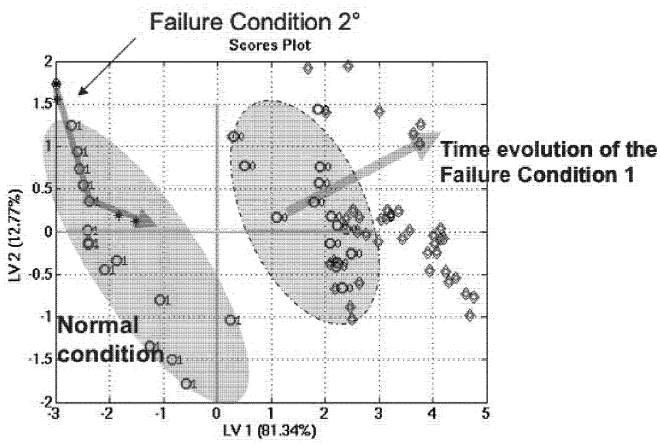

Figure 3: The plot of the first two Latent Variables of the PLS-DA model shows the recognition of failure with respect to the normal operation. Arrows indicate the time progression of the malfunctioning condition.

3. Space Experiment: the ENEIDE Mission

With the support of the Italian Space Agency (contract N° I/040/05/0), a space prototype of electronic nose was developed. To test the electronic nose in the International Space Station (ISS) during the ENEIDE mission (15 -24 April 2005), an experiment in the technology test context has been planned.

In order to fulfil the "space qualification" the instrument was completely re-designed in all its parts and a set of original solutions have been implemented in the prototype. In particular, novel low power electronic interface and pneumatic system have been designed to achieve power consumption less than 1 W and a weight of 0.8 Kg. Figure 4 shows the space prototype of the electronic nose during the ENEIDE mission with the Italian astronaut Roberto Vittori. On board tests of the prototype included a simple experiment aimed at measuring, the air in the close environment of the instrument. This test is fundamentally a technology test and its scope was to verify the functioning and the sensor stability in the experimental sessions. The results indicate a substantial constancy of the air quality during the experiment and, on the other hand, the same good reproducibility of the "ground version" electronic nose.

4. Conclusions

The monitoring of the air quality of the closed environment is a complex task involving a large number of chemicals and the electronic nose approach can be considered an optimal measurement approach. In this paper the performance of an electronic nose have been illustrated in ground and space based experiments.

Figure 4: The space prototype during the space experimental session with the Italian astronaut RobertoVittori.

In ground experiments the instrument demonstrated its ability to capture the malfunctioning of biofilters for animal cages and bioreactors chemicals removal. Space experiment has shown that the main functionalities of the instruments are preserved at microgravity conditions and eventually, that the electronic nose technology is sufficiently mature for space applications.

5. References

[1] K. Persaud, A. Pisanelli, S. Szyszko, M. Reichl, G. Horner, A smart gas sensor for monitoring environmental changes in closed systems: results from the MIR space station, Sensors and Actuators B 55, 1999, 118-126

[2] M. Ryan, H. Zhou, M. Buehler, K. Manatt, V. Mowrey, S. Jackson, A. Kisor, A. Shevade, M. Homer; Monitoring space shuttle air quality using the Jet Propulsion Laboratory electronic nose, IEEE Sensors Journal, 4, 2004 337-347

[3] Mergeay M., Verstraete W., Dubertret G., Lefort-Tran M., Chipaux C. Binot R.; MELISSA - a micro organisms based model for CELSS development, Proceedings of the 3rd symposium on space thermal control & life support system. Noordwijk, the Netherlands, 3-6 Oct. 1988, 65-68

[4] Andrew Wilson (ed.), 2005. Microgravity Applications Programme: Successful teaming of science and industry. ESA publication SP-1290, Noordwijk the Netherlands, pp. 270-280

[5] A. D'Amico, C. Di Natale, A. Macagnano, F. Davide, A. Mantini, E. Tarizzo, R. Paolesse, T. Boschi; Technology and tools for mimicking olfaction: status of the Rome Tor Vergata Electronic Nose, Biosensors and bioelectronics 13 (1998) 711-721

[6] Willers H., de Gijsel P., Ogink N., D'Amico A., Martinelli E., Di Natale C., Van Ras N., Van der Waarde J.; Monitoring of biological odour filtration in closed environments with olfactometry and an electronic nose, Water Science and Technology 50, 2004 93-100.
[7] E.Martinelli, G. Pennazza, R. Paolesse, E. Milian, J. Albiol, F. Godia, N. Van Ras, J. Van der Waarde, D. Demey, C. Di Natale, A. D'Amico, 3rd IEEE Sensors Conference, Vienna (Austria), 24-27 Oct 2004.