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eNoses as a Tool to Measure Odour Nuisance Caused by Restaurants

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Cooking smells originating from nearby located restaurants quite often annoy people living in the inner cities. Currently it is difficult for authorities in the Netherlands to act against this type of odour nuisance. In order to map the hindrance situation around restaurants in a more effective way, numerous continuous odour-monitoring campaigns using eNoses have been successfully carried out.

1. Introduction

From 2005 Comon Invent, VITO and DCMR EPA have co-operated in several projects where the applicability of the eNoses has been demonstrated (Bootsma et al., 2010; Bootsma et al., 2011; Milan et al., 2012; Bootsma et al., 2013). The initial project was an eNose monitoring campaign at a petrol service station in the Rotterdam Region in order to find the cause of a 18-years lasting odour hindrance situation. The second was a pilot project to demonstrate the eNose potential as a pro-active odour management tool in the heavily industrialized and densely populated Port of Rotterdam.
Another project was a full-scale eNose research programme, which started in 2010. The main objective of this 3 years research programme was to investigate further the eNose potential as an odour management tool for the stakeholders in the Port of Rotterdam aiming at reducing odour exposure and thus odour impact. The second objective was to investigate whether the eNose can also be used as a safety management tool for fast recognition of accidental gasses resulting in incidents. The programme was successfully completed in 2013. At present a grid comprising over 300 eNoses is operational in the Port of Rotterdam.

1.1 eNose monitoring campaigns

One work package within the full-scale eNose research program was the mapping of the hindrance situation of specific companies with a long track record of odour complaints with an eNose grid. A grid of eNoses is installed at and around the company to provide a 24/7 monitoring of the company emissions and of the odour situation in the neighbourhood (receptor level). The residents are given the opportunity to record their odour observations via a dedicated Internet webpage. Continuous monitoring of odour emissions is in this way an important odour-mapping tool as it enables to find the specific cause of odour nuisance at the company.
One of the monitoring campaigns was performed at a nut burner factory. The regular odour report, based on olfactometry and dispersion calculations, was not able to give a representative picture of the odour situation, as it could not forecast the hindrance situation. A better representative picture was obtained by monitoring 24/7 the odour emissions of the nut burner factory. For this, eNose readings had to be related to human odour observations of burned nuts. It turned out that a clear relationship was found on emission level between odour observation and eNose readings. More important, also a clear relationship was found at receptor level between odour observations in the residential area and mobile e-nose readings.
Another monitoring campaign was performed at a potato processing plant. Besides 24/7 online monitoring, reference fingerprints of the eNoses were determined by dynamic olfactometry. This resulted in the creation of a reference set with distinctive fingerprints. With this fingerprints the eNose network on-site could detect the emissions of the different sources.

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1.2 eNose monitoring campaigns at restaurants

Cooking smells originating from nearby located restaurants quite often annoy people living in the inner cities. Currently it is difficult for authorities in the Netherlands to act against such odour nuisance. An underlying reason for this is that supervisors experience difficulties with the implementation of Environmental Control Acts, which should allow them to act effectively against malodours originating from restaurants. To be more specific, at this moment the Dutch Environmental Control Act offers insufficient grip to restaurants supervisors to help them substantiate the terms “effective odour measures” and “acceptable hindrance level”. In order to assist in resolving this matter, in 2014, an extensive investigation using eNoses has been carried out in which continuously odour-monitoring campaigns were conducted at 10 different restaurants located all across the Netherlands. The study was co-financed by the DCMR Rijnmond EPA and the Dutch Ministry of Infrastructure and Environment. The research was conducted by Comon-Invent and VITO.

2. Method: online Enose technology

The eNose is an instrument comprising an array of gas sensitive sensors. When exposed to oxidizing or reducing gas mixtures all sensors in the eNose respond and give sensor signals. Periodically the sensor signals of the array are read-out simultaneously and transmitted via an online data communication link to a database on a remote computer system. This database stores all raw eNose read-out signals. The software on the remote computer evaluates each incoming eNose reading prior to storage. The evaluation process has two levels. The first level is an anomaly detection feature. The second level is pattern recognition. The anomaly detection is a first order signalling function. It is based on the exceeding of the alarm levels by the eNose output signal. It indicates that the eNose detects a change in its surrounding air composition. The passing of a gas mixture causes this change. Since a lot of gas mixtures hold a fraction of odourous compounds, the detection of an anomaly can be a warning of a risk of odour nuisance. However, the gas mixture responsible for the anomaly is not necessarily odourous. Therefore the eNose is applicable for odourous and non-odourous gas detection.

The anomaly detection provides qualitative information at a nominal scale. Pattern recognition is a more advanced method for evaluation of the incoming raw eNose data. For this method the incoming eNose reading is transferred to a pattern. This pattern is compared to a set of reference fingerprints stored in a library. If the pattern matches to one of the reference patterns, it is possible that the eNose is exposed to the same gas mixture by the time the reference pattern was determined. Hence we call the reference patterns classified fingerprints of the eNose. The classification process too is part of the eNose training.

In accordance with the NEN:NTA9055 (Dutch technical agreement for the use of eNoses) several reference sources are used for the classification process:

1. Field sources: Recorded human observations together with eNose readings:
    a. Complaints;
    b. Surveys of odour panels;
2. Laboratory sources: Laboratory testing of known gases together with eNose readings:
    a. Analytical testing using calibration gasses;
    b. Olfactometry testing using field odour samples according to the EN 13725.

3. Results and discussions

Continuously odour-monitoring campaigns were conducted at 10 different restaurants located all across the Netherlands. Various types of restaurants participated. These include restaurants serving Asian food (Indonesian and Vietnamese), Mediterranean food (Italian and Greek), Japanese food (Sushi) and Dutch food (pancakes). Also “meat-based” restaurants were selected (Grill restaurant and hamburger fast-food establishment) For this purpose of this study a network of eNoses was installed for a few weeks at and around each restaurant to investigate the emissions to the surroundings. Simultaneously the residents were given the opportunity to fill in their (mal)odour observations via an Internet webpage. Supervisors also recorded their odour observations during the monitoring campaigns. Also the odour concentrations were measured via olfactometric assessments.

3.1 eNose readings at emission level

Figure 1 shows the eNose readings of eNoses close to the exhaust of two restaurants for a period of two weeks. The eNose readings depicted in Figure 1 shows a clear on-off regime indicating that emission patterns are being monitored. Thus with eNoses installed close to the restaurant’s exhaust trends are recorded which obviously correlate with the operating times of the establishment which is monitored.

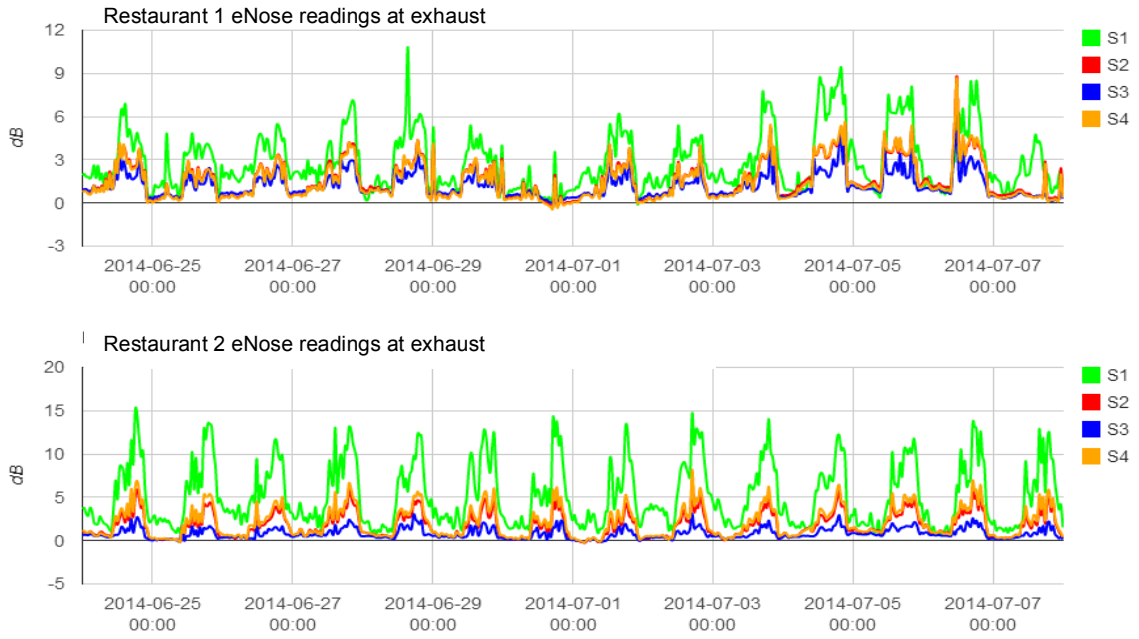

Figure 1: Raw eNose data of the exhausts of restaurants 1 and 2 show a good relationship with the operating times of the restaurants being monitored.

3.2 eNose readings at receptor level

Figure 2 shows an example of simultaneous eNose readings at the emission level and at the receptor level. Clearly eNoses not only respond to the cooking emissions at the sources of the restaurant (upper figure), but also away from the restaurant at the receptor level where residents experience hindrance (lower figure). Similarly clear emission–receptor relations have been found for most of the restaurants. Only for two restaurants no clear emission-receptor relations were found because of factors such as the distance between receptor and exhaust and the prevailing unfavourable wind direction during the monitoring campaign

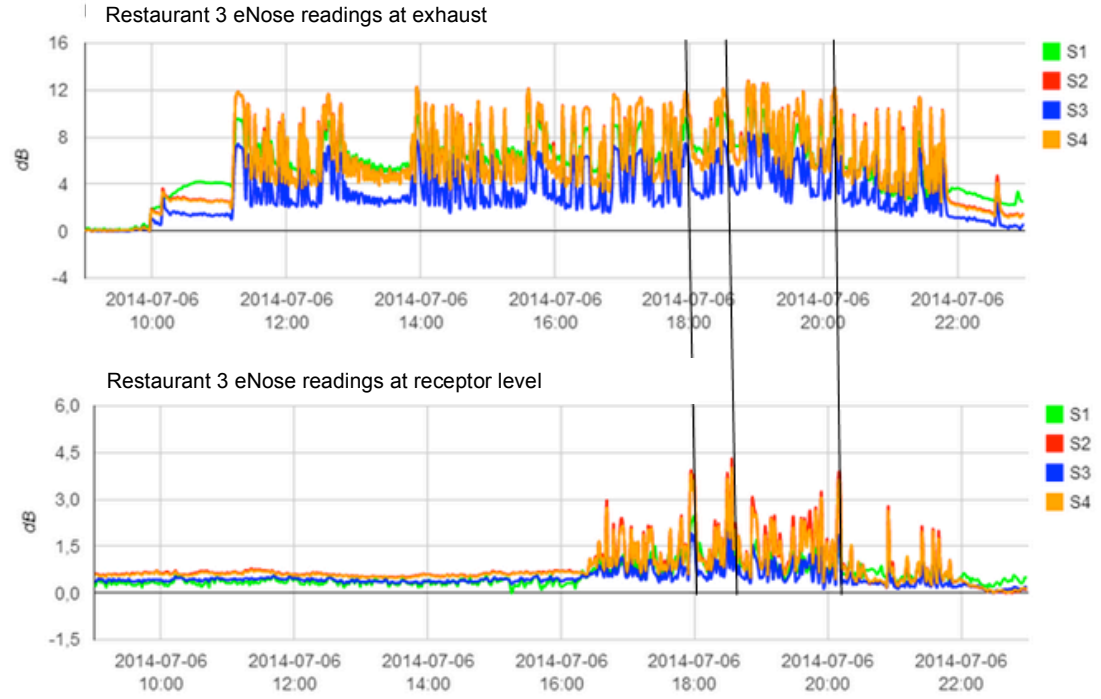

Figure 2: Relation between the raw eNose data of the exhaust of restaurant 3 and the raw eNose data at the receptor level of restaurant.

3.3 Relations between eNose readings and recorded human odour observations at the field

For 9 out of 10 restaurants relationships were found between the eNose readings at the emission and/or receptor level and the human perception of cooking smells around the restaurants. Residents were asked to record their odour observations. Also supervisors recorded their odour observations during the period of the monitoring campaign. These recording times were plotted in the eNose graphs. Figure 3 shows an example of a malodour perception of a resident and the eNose readings of both the emission level and receptor level at the recorded time.

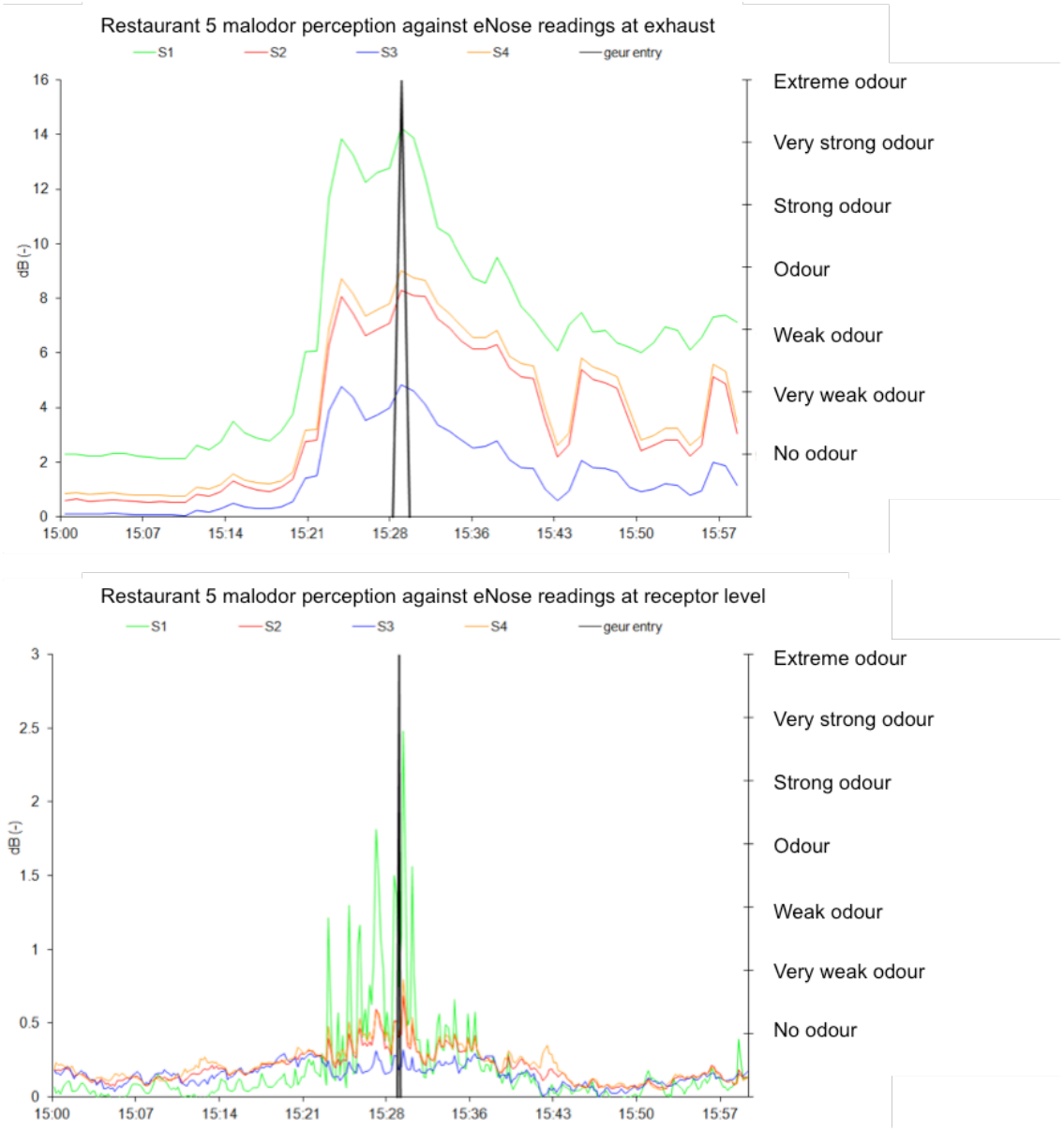

Figure 3: Raw eNose data of the exhaust of restaurant 5 and the raw eNose data located at the balcony of a nearby living resident (15-05-2014). The resident recorded an extreme odour smell between 15:00 and 15:30 (black lines).

3.4 Relations between eNose readings and olfactometric assessments in the laboratory

Odour concentrations of the emissions of 7 out of 10 restaurants were measured according to EN 13725. The air samples were also used to study the relation between the eNose readings and ascending odour concentrations of the restaurant air using an olfactometer. In this manner eNose sensitivity curves for each of the 7 restaurants were created. Moreover by combining all the data of all individual sensitivity curves, a generic eNose "restaurant-sensitivity-curve" is constructed. Figure 4 depicts this curve. The long-term objective is that authorities could use this curve to translate eNose signals measured in the field into indicative values for restaurant related odour concentrations. Additional research is required before this sensitivity curve can be used to act effectively against malodours originating from restaurants.

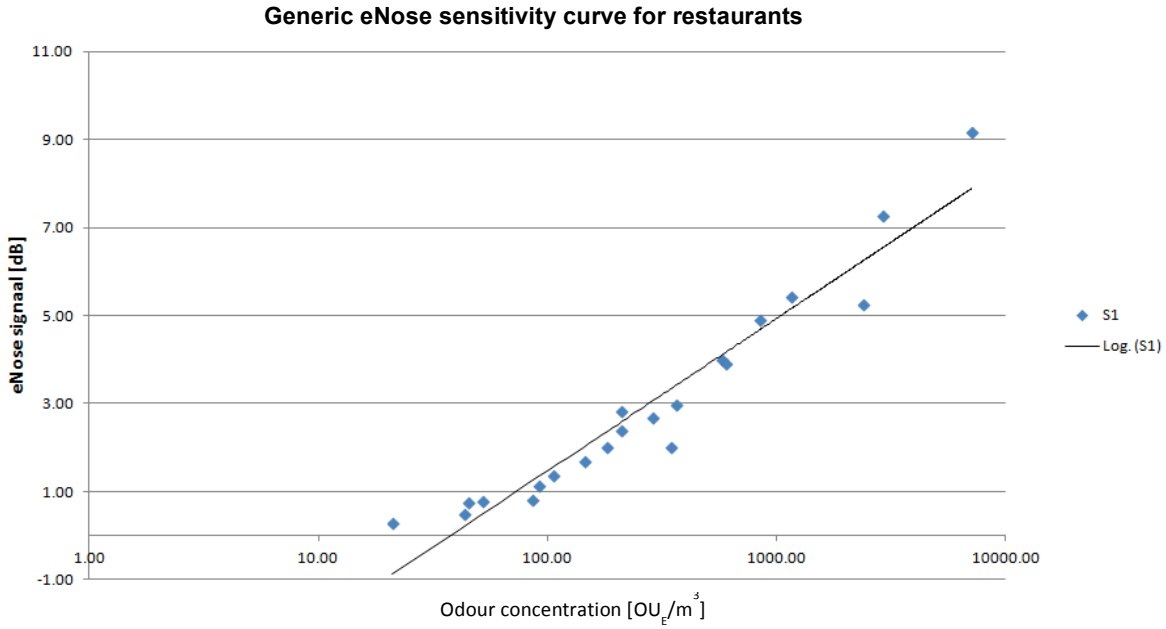

Figure 4: Generic eNose "restaurants-sensitivity-curve"

4. Conclusions

The results of the research demonstrate that the eNose technology allows to make a representative picture of an odour situation around a restaurant. The eNoses respond to the cooking emissions at the sources of the restaurant, but also away from the restaurant at the receptor level. The results showed clear relations between the hindrance of the residents and the emissions of restaurants. These results allow supervisory authorities to use the eNose to objectify and substantiate the odour perception of residents. Another result is the construction of a generic eNose "restaurant-sensitivity-curve". The long-term objective is that authorities can use this curve to translate eNose signals into indicative values for restaurant related odour concentrations. Additional research is required before this sensitivity curve can be used to act effectively against malodours originating from restaurants. Figures and tables

Acknowledgments

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