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Application of ODEMS (Odorant Dispersion and Emissions Monitoring System) to Measure Odorous Emissions from Composting Plant

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Odour annoyance represents a very important issue of societal and industrial perspective. It can be due to the intrinsic character of the odour, its frequency and the moment of the perception. Location of industries depends on their odour acceptability in the neighbourhood. As 13 to 20% of the population in European countries would be annoyed by environmental odours, stringent regulations are being enforced for odor monitoring and recently, several works have been carried out to determine suitable and valuable strategies/methods to limit odor annoyance.
Industrial and agricultural activities generate atmospheric pollution and olfactive nuisances due to the emission of a complex mixture of volatile compounds. Hydrogen sulphide (H_2S) and ammonia (NH_3) are clearly identified within composting plants (Cabrol et al, 2012) and due to their high olfactory impact, have to be monitored as mentioned in a report of the French Environmental and Energy Management Agency (ADEME, 2012).
ODEMS is a system composed by a network of miniature and autonomous sensors combined with reversed dispersion (Figure 1) and dispersion (Figure 2) modelling systems and enable to provide reliable spatial and temporal information down to the low ppbv level. The miniaturized cost-effective sensors Cairsens are based on amperometric detection and are developed by Cairpol company. Ammonia and hydrogen sulfide sensors have been deployed within a composting plant for determining the odorous sources and evaluating the real impact on the neighbourhood. After a period of data collection, considering weather conditions, this study revealed that this system is also able to predict the impact of a site-specific activity.

1. Introduction

Nowadays, around 20% of the European population is affected by olfactory discomfort (Bokowa, 2010). This phenomenon has resulted in the enforcement of environmental legislations to control odors emissions. As an example of the growing awareness about odors annoyances, Article L220-2 of the Environment Code in France highlights that "Is considered as air pollution [...], the introduction by Man, directly or indirectly, or the presence in the atmosphere and enclosed areas of chemical, biological or physical agents resulting in prejudicial consequences likely to [...] cause odor nuisance."
The presence of such compounds in the ambient air primarily is due to industrial and agricultural activities such as waste processing, storage and fermentation of organic materials (compost, wastewater treatment sludge), or livestock breeding. To raise the level of public acceptance, and to avoid potential financial penalties, industrials have to control as better as possible odors emissions.

As plants are often expanded on wide areas, both monitoring and control of odors emissions require combined solutions of analyzers and modeling technologies (Charles et al., 2007; Pan and Yang, 2009). Notwithstanding the nature and the quality of models algorithms, the reliability of the results is strongly linked to the number of measurement points. A representative assessment of the current situation is obtained by a network of readings (Mamduh et al. 2012) within a given territory provided by a high number of cost efficient devices (Othman and Shazali, 2012).
Sulphur and nitrogen compounds are the main odorant families detected from composting plants. Due to the high olfactory impact of these compounds (odor threshold) (Van Gemert, 2011), they have to be monitored in real time as it was mentioned in ADEME, 2012.
This paper presents main results of ODEMS (Odorant Dispersion and Emissions Monitoring System) which has been deployed in a composting plant in the South of France.

2. Materials and methods

2.1 Description of the composting plant

The composting plant under study is located in south of France near Alès. This plant produces around 5 000 t of compost with approximatively 25 000 t of entries per year. In this plant, green wastes, maturation step and final compost are stocked outside. The fermentation step is done realized in a building equipped with a system of chemical treatment of gaseous exhausts (Figure 1).

Figure 1: Localization of the sensors

Figure 2: Picture of the fermentation area

Figure 2 presents a front view of the fermentation area. The white color is due to the emission of water vapor during this exothermic process.
Two major sources of odours have been identified on this site: the fermentation process building and the outdoor storage area (several windrows with the number depending of the activity localized in this area). The site is equipped with 12 sensors Cairsens (Cairpol, France) for H_2S and NH_3. The localization of each couple of sensors is shown in Figure 1. The ODEMS equipment is completed with a local weather station.

2.2 Sensors (Cairsens) and autonomous wireless measurement point (Cairnet)

The miniature detector used in this study (Figure 3a) is based on amperometric technology.
To maintain a constant air flow through the sensor, a dynamic air sampler was used. Combined with a patented buffer, a highly sensitive electronic circuit and a microcontroller, Cairsens sensor is able to provide low level accurate measurements.
High definition real time monitoring of wide areas can then be performed by implementing a network of Cairnet autonomous wireless measurement points (Figure 3bincluding Cairsens sensors.

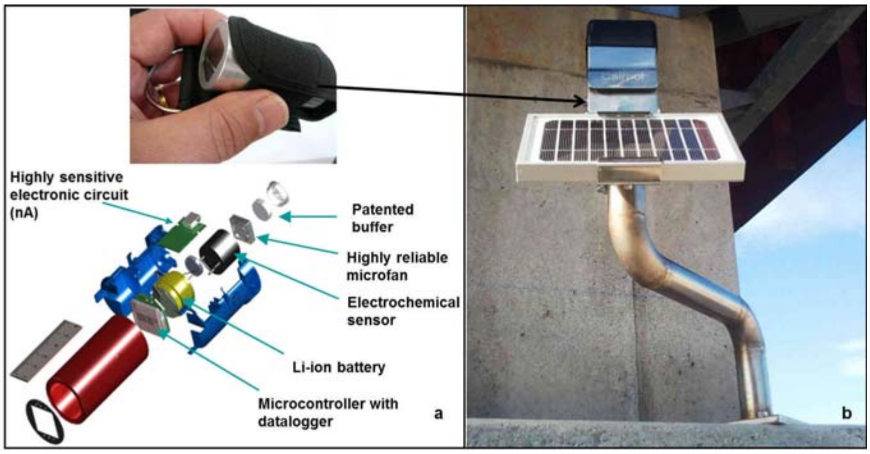


Figure 3: (a) Photography of a Caisens and schematic representation of its main components, (b) Photography of the autonomous wireless measurement point.

2.3 Softwares

The system developed includes two softwares tools, each having particular functions.

The huge quantity of data generated by such system has been managed using the software named CairMap®, (ISEO, Bidart – France). This user-friendly interface provides easy and continuous monitoring of the emission of diffuse pollution compounds at low concentrations. Graphical modelling has been performed using Aria View3D® software (Aria technologies S.A., Boulogne – France) based on micro-swift-spray model (Moussafir, 2010, ARIA, 2016). ARIA View 3D® computes 3D wind field and concentration using the following calculation modules:

SWIFT is a 3D wind field model for complex field. It produces a mass-consistent wind field using data from a dispersed meteorological network. Temperature and humidity fields can also be interpolated with SWIFT. This module generates also the turbulent components, which are used by the dispersion module. The main steps of the program are the determination of an initial field by interpolation of available measured data, the adjustment of the final non-divergent field, the consistent with boundary conditions and atmospheric stability and the determination of turbulent fields.

SPRAY 3.0 is a three-dimensional “Lagrangian particle dispersion model” developed by Arianet S.r.l. in collaboration with Aria Technologies SA. This code reproduces the transport, dispersion, dry and wet deposition of airborne chemically inert species released in meteorological complex conditions (low wind speed, flow over complex topography), often marked by spatial and temporal inhomogeneity of the meteo-diffusive variables (e.g. vertical wind-shear, breeze due to the presence of terrain discontinuities).

The emitted gas concentrations from the defined emission sources are assessed from data recorded by sensors and based on the site‘s nominal emissions. The used method consists on calculating the dispersion on a small scale (figure 7) where the sensors are implemented. Then, a comparison is made between the calculated concentrations and the measured ones at the sensor measurement points. Based on this comparison, a mathematical regression method enables the determination of the corrective coefficient that should be applied to the nominal emissions. The corrected emissions are then used in the final calculation. This new method ensures the best emissions’ estimation based on the measured values by the sensors network installed on the site.

The new method requires the sources localizations knowledge and the data of an emission nominal value for each calculated species. The value could be given by the customer based either on field sampling and laboratory measurements or by numerous studies.

3. Results and discussion

An example of this system application is described in this section. The studied period is two days (20 and 21 of July in 2015). Reverse modelling domain covers 250m x 270 m^2 centered on the composting plant with 2x2m^2 horizontal resolution. Vertical grid goes up to 300 m with the first mesh at 1.2 m.

3.1 Data collection

3.1.1. Weather data

The collected weather data include wind speed and direction and temperature. All these results are used by SWIFT® software to design a three dimensional meteorological field (Figure 4).

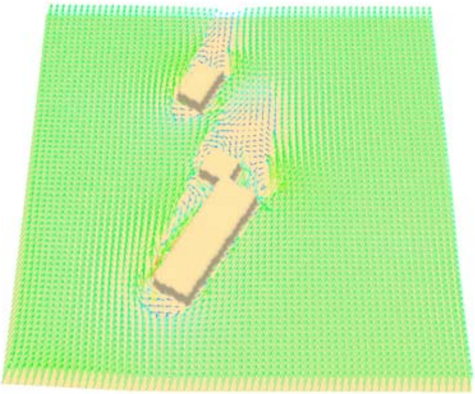
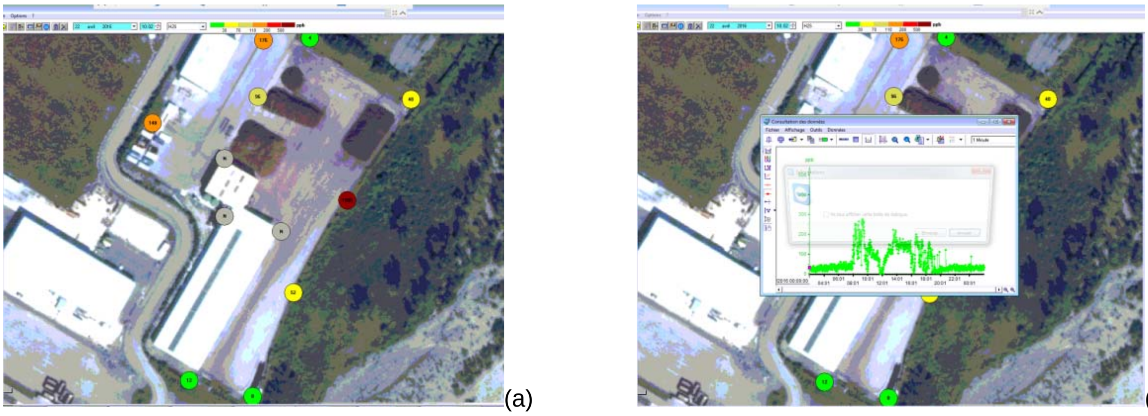


Figure 4: 3D weather field produced by SWIFT® software.

3.1.2. Sensors

All measurements are collected with Cairmap®. For each sensor, all data are available, and displayed on a map or within a time dynamic table as seen in Figure 5.



(a) (b)

Figure 5: (a) H_2S sensor measurements on the site, (b) An example of H_2S sensor measurements along one day

3.2 Reverse modelling and dispersion model

With all collected measurements, a reverse modelling approach is applied using the SPRAY 3D® software. Reversed modelling results can be used in two ways. First, temporal dynamic of pollutant concentrations for preselected sources can be monitored (Figure 6).

(a) (b)

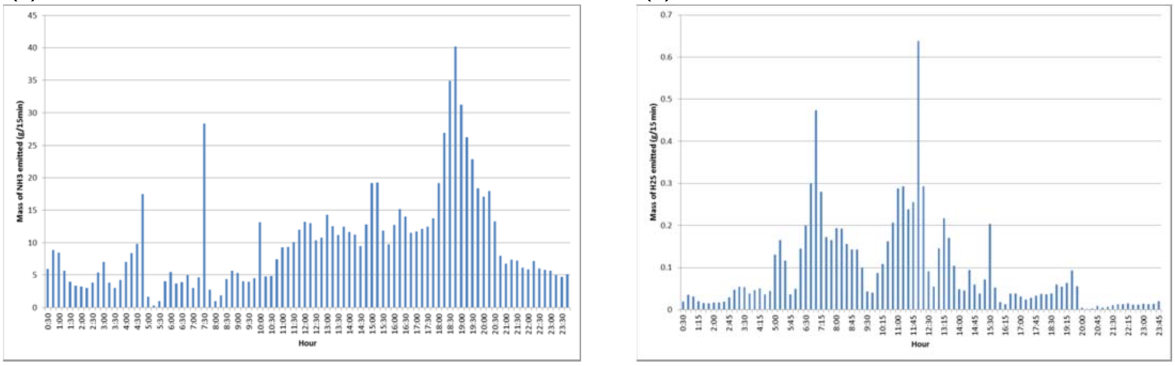
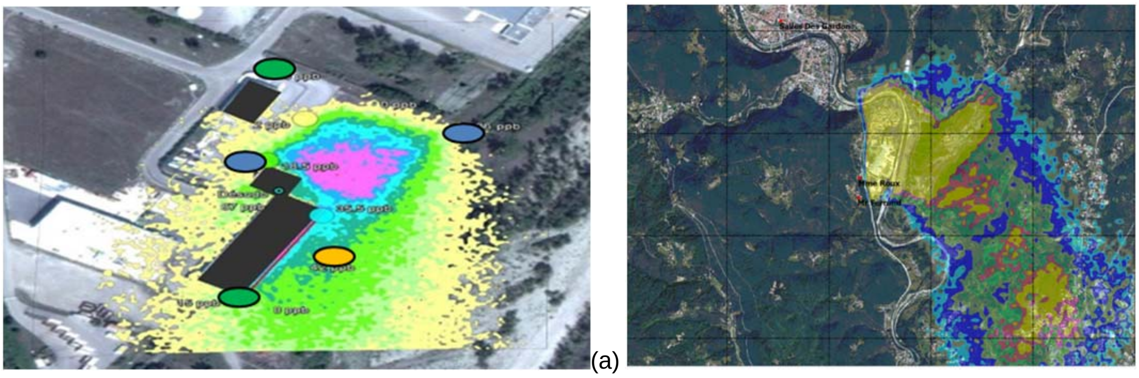


Figure 6: (a) NH_3 calculated emissions for compost windrows; (b) H2S calculated emissions for the fermentation process building

Secondly, the mapping of pollutant emissions can be assessed. This map can reveal the main emission sources of odourous pollutants..
Then, this relevant and valuable tool can be used to define strategies to limit complaints by some suitable changes (delay, process modification, …) of process operation . Hence, within the study period, it has been highlighted that the main odorant emission sources are the compost windrows (Figure 7).



(a)

(b)

Figure 7: (a) Determination of emission sources by reverse modelling, (b) Dispersion model of NH3

With the calculated pollutant emission fluxes for each source, a dispersion map of each pollutant on the neighbourhood of the composting plant is obtained by using ARIA View 3D® software (Figure 7b).
This figure shows different areas with high level of ammonia. Some are not pointing in direction of population but others are on buildings and inhabited areas, so potentially generating odour annoyance in the neighbourhood.

4. Conclusion

As seen in this paper, the system developed in a three years program is effective and gives several levels of information for the industrial. The first one is the immediate evaluation of the gaseous emissions of the composting plant, the second one is the localization of the main sources of pollutants and the last one is the visualization of the impact of these emissions on the neighbourhood. In the future, after a few months of data collection and with the integration of industrial activities, ODEMS system will be able to predict the impact of a specific activity on the neighbourhood impact to warn the industrial to delay or modify the activity he plans.

Acknowledgment

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