ODEMS (Odorant Dispersion and Emissions Monitoring System), smart tool to measure and predict the odorous emissions of a composting plant activity

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INTRODUCTION

The odour annoyance represents a very important issue for societal and industrial perspective and activities due to the intrinsic character of the odour, or to the frequency of the perception. In general, the industries' locations depend of their odour acceptability in the neighbourhood. Because of around 20% of the European population are annoyed by environmental odours, the rules and the regulations have been enhanced in the odour monitoring's field[1]. Hence, a developed sensor in order to estimate the impact of the industrial activities on neighborhood will be very important and useful.

The main emission sources of odorous compounds are related to the industrial and the agricultural activities. The molecular compounds such as hydrogen sulphide (H_2S) and ammonia (NH_3) are identified clearly on composting plant. Due to their high olfactory impact, H_2S and NH_3 have to be monitored in real time as it was mentioned in the French Environment and Energy Management Agency (ADEME) report[2].

Many commercialized analyzers[6], including fluorescence-based detection or flame photometric detector, provide high accurate measurements at a given time and place, however, such analytical devices are expensive and are not easily transportable on the field. From where, these apparatus could not be mass deployed and could not give consequently a full picture of the current pollution. Moreover, spatial and temporal dimensions, which define diffused pollution, are then lost.

Odorant Dispersion and Emissions Monitoring System (ODEMS) is composed of miniature and autonomous sensors network combined with reversed and direct dispersion modeling systems. The ODEMS provides accurate and reliable spatial and temporal information down to the low ppbv level. NH_3 and H_2S sensors have been implemented on the composting plant in order to determine the odorous sources and to evaluate the real impact on the neighborhood.
According to Devos *et al.*, human olfactory thresholds, define the concentration at which all panelists recognize the odor, for three of the most frequently encountered species that are presented Table 1.

Table 1 : Human olfactory thresholds for H_2S, CH_3SH and NH_3

Compound	Human olfactory threshold	Smell
H_2S	18 ppbv	Rotten egg
CH_3SH	1 ppbv	Cabbage, garlic
NH_3	5-6 ppmv	Pungent, irritant

After a certain period of data collection, the ODEMS, associated with meteorological conditions, is also able to predict the impact of the site-specific activity. The ODEMS project took 3 years of development and the obtained results during the composting plant field test will be presented. By focusing on H_2S, the World Health Organization recommends "to avoid substantial complaints about odor annoyance among the exposed population, hydrogen sulphide concentrations should not be allowed to exceed 4.7 ppbv, with a 30-minute averaging period"[5].

The ODEMS experimental setup

The main objective of the ODEMS project is to measure and predict the odorous emissions of a composting plant activity. The ODEMS is considered as an integrated tool that will support the composting plant operators in managing and reducing the odorous compounds emissions for a better population acceptance and for avoiding potential financial penalties. The ODEMS is a combination of technological bricks: ODEMS tools, Wireless Sensors Network, Dispersion Model and Predictive and Decision support tools (Figure 1).

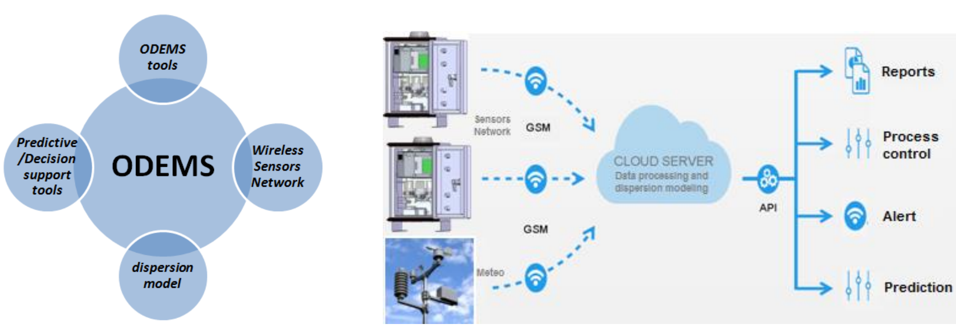


Figure 1. ODEMS principle and structure

ODEMS tools: The composting plant is composed of several storage areas of green waste and compost and covered area for the fermentation process. All those areas are supposed to be odors emission sources. The ODEMS tools are designed to optimize the number of sensors and their positioning in order to improve the dispersion models for the odorous sources' determination and for evaluating the impact on the neighborhood. The ODEMS tools Input parameters are: area view of the plant and its limits, a wind rose, odorous sources areas, sensors exclusions zones and neighborhoods positions (Figure 2).

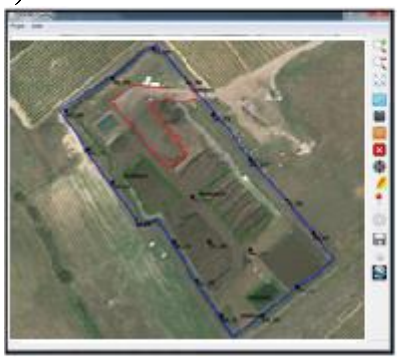


Figure 2. ODEMS tools

Wireless Sensors Network: A new generation of miniature cost effective sensors based on amperometric detection (Cairsens), has been developed to continuously monitor H_2S and NH_3 at ppbv levels. When combined with wireless communication, a solar panel and a backup battery, one can set up an autonomous network of sensors (Cairnet).

Dispersion model: 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 inhomogeneities 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 estimated based on the data given by sensors based on the site's nominal emissions. The used method consists on calculating the dispersion on a small scale (figure 6.b) 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 allows to determine 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.

Predictive and decision support tools: the aim of this module is to support operators predicting and anticipating impact of any process tasks on odorous emission. Operators must define different numbers of processes' scenarios including one or more tasks like: sifting compost, turning compost in windrows, opening doors of fermentation building or any other specific task that can generate odorous emission. This tool operates on two different phases: first phase (Figure 3.a) is a system-training phase where system will generate a database while the composting plan is operating on different scenario and different metrological conditions. Database includes for each defined scenario: metrological condition (temperature, wind velocity and direction), sensors measurements data and emission factor for each defined odorous emission source area calculated using the dispersion model.

Second phases is the prediction phase where operator can decide if the scenario of the day and the system will assign emissions factors to this scenario using the database created on the first phase. Dispersion model can than simulate and generate an odorous graphical dispersion map according to the day's meteorological conditions.

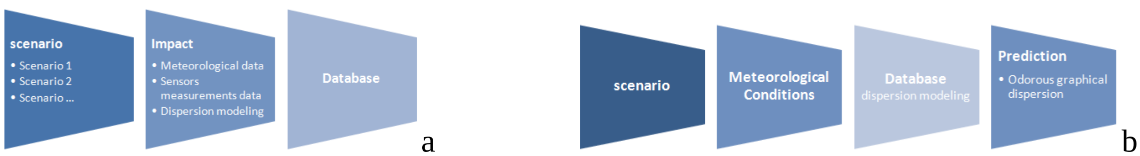


Figure 3. Database generating phase (a), prediction phase (b)

Results and discussion

The compost plant site for field test has been chosen for its specific complex topography. The compost plant, presented in figure 4.b, has been constructed in a small valley (figure 4.a). A number of habitations are situated in the valley's north side. The plant is composed of several storage areas of green waste and compost. In order to limit maximum odor annoyances, the fermentation process, which is considered the main emission source, is performed in a covered area. The fermentation process consists in blending brown waste and vegetal matter under aerobic conditions. Swaths are regularly blended in order to obtain homogeneous compost. Needless to say that this step constitutes a crucial moment in term of odor diffusion.

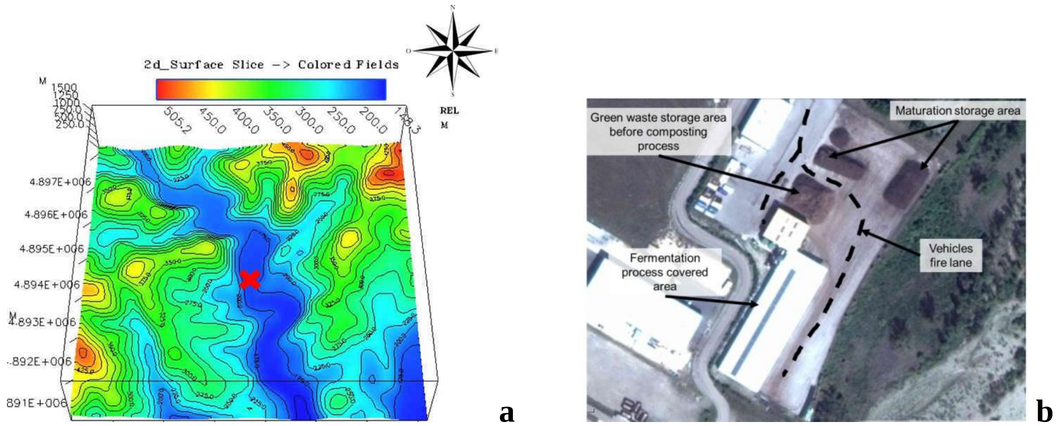


Figure 4: Graphical modeling of the valley (a), Aerial view of the compost plant (b)

Using ODEMS tools, we define the number and positions of sensors. Figure 5.a represents the result with 18 sensors and their positions on the compost plant in order to have the higher reliability index. Figure 5.b represents another proposition where operator reduces the number of sensors to 12 having a reliability index of 74 %.

Figure 6 represents the dispersion modeling results on a large scale for ammonia (Figure 6.a) and a small scale for hydrogen sulphide (Figure 6.b). This simulation was done with two emissions sources: windrows and fermentation building door (corresponding to the yellow areas in Figure 6.b). Those two emissions sources represent a scenario where doors of fermentation building are open and operator is turning compost in windrows.

Correlations between measured value using CAIRNET sensors and calculated value of hydrogen sulphide and ammonia concentration in ppb are represented in Figure 7.a and b. Correlations was done on a spatial point where sensor number 12 is positioned.

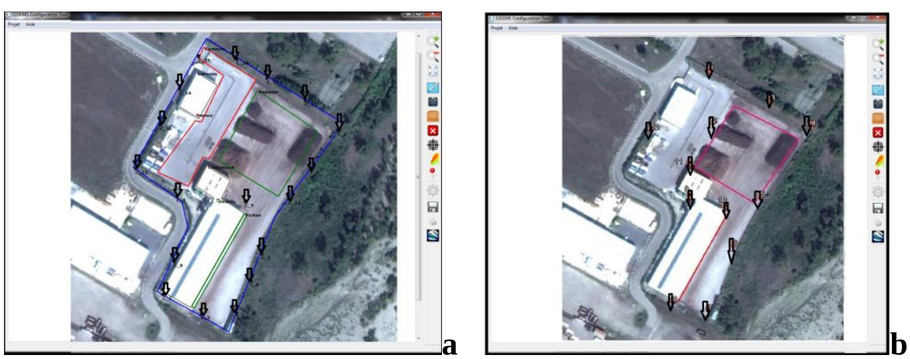
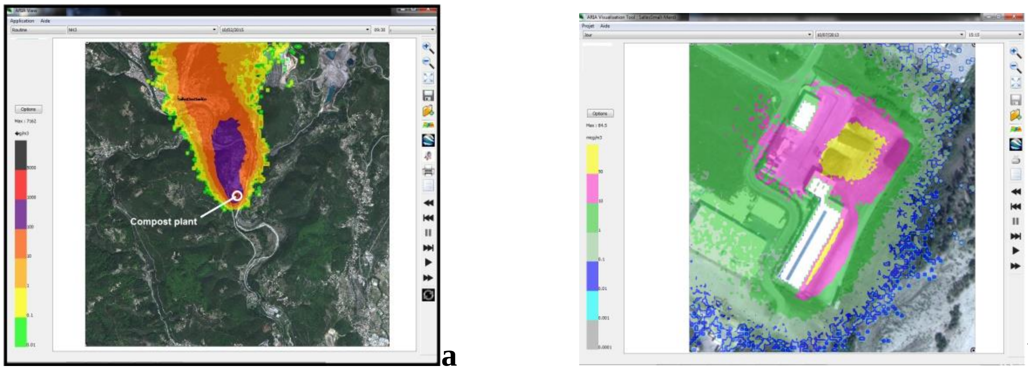
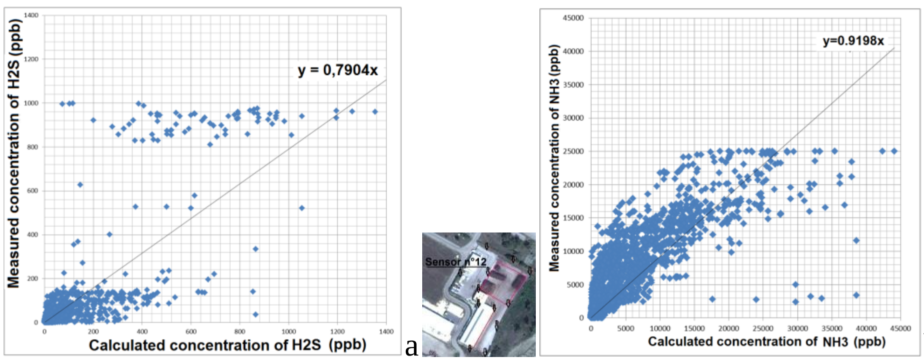


Figure 5: ODEMS tools results: 18 sensors positioning (a), 12 sensors positioning (b)



a b

Figure 6: Large-scale dispersion for NH3 (a), small-scale dispersion for H2S (b)



a b

Figure 7: correlation between measured and calculated value on sensor n°12 (a) H2S (b)NH3

SUMMARY

These first qualitative results have shown the very promising future of this "odor-friendly" system of managing process. Modules that make ODEMS up include ODEMS tools, Wireless Sensors Network, Dispersion Model and Predictive and Decision support tools have been developed and tested on a compost plant.

After a laboratory and field validation of hydrogen sulphide and ammonia sensors, preliminary results obtained using the network of sensors have illustrated the potential of such system for field monitoring of odors. Combination of sensors network and numerical software lead to a complete system for process managing.

Complete system is installed in the compost plant and the database is generated for predicting models. The next step is the coupling of those four modules creating a friendly Human Machine Interface (HMI) and validation of the predicting and decision support tools.

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