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REAL-TIME MANAGEMENT OF ODOUR ON WATER TREATMENT PLANT USING A 3D SIMULATION TOOL COUPLED TO ON-SITE SENSORS

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Abstract: Odours are a major nuisance near industrial sites such as waste water treatment plants. To be able to forecast and to follow in real-time the dispersion of smells around the plant would be a major improvement with respect to neighbours relation as well as the site management and planning. In such a context, the SIAAP, which deals with waste water for the entire region of Paris, France, has developed and implemented on their sites of Seine aval, Marne aval and Seine amont an innovative tool called SYPROS. SYPROS is based on the 3D CFD dispersion tool Fluidyn-PANEIA using a Lagrangian puff model for the real-time procedure and a source definition module to determine the source emission rates in real-time (i.e. with a 30 minute delay in continuous mode). To this end the concept of real-time adjustment of the source emission, the so-called remapping process, has been implemented. A case study of the implementation of the comprehensive tool SYPROS on the Seine aval site is described.

***Key words**: Real-time odour management, remapping, 3D CFD dispersion model, Waste Water Treatment Plant, Lagrangian puff model, Source emission definition*

INTRODUCTION
Since 1970, the S.I.A.A.P.[2] has been the central authority for water treatment in Paris region (8 million inhabitants today in 180 cities). Every day, 3 million m^3 of water are treated in 5 plants including the massive Waste Water Treatment Plant (WWTP) Seine aval located in Achères, whose 1.8 M m^3/day of flow rate treated makes it the largest in Europe. The everyday operation of these plants generates odorous compounds that can be an inconvenience or even a nuisance for the nearby populations, according to the exploitation modes and to the weather conditions. Some of the principal compounds with major odorous impact are the Total Reduced Sulphur compounds (TRS). Preventing their propagation is a real challenge for the plant trying to improve relations with its neighbours. Since the beginning of the 90's, the SIAAP has established an Environment Observatory dedicated to 3 of these plants, to closely follow the odour pollution through TRS monitoring and take measures to limit it, by identifying the source of the emissions. Until 2009, the monitoring was mainly supported by systematic actions. However they do not allow a continuous follow-up in time and space of the odorous pollution of the plant. The SYPROS[3] numerical system was therefore developed in order to improve the odours monitoring on sites by a real-time and forecasting management of the odour nuisance. SYPROS includes three functions:

- A "real time" function to produce uninterrupted and up-to-date production of odour concentrations maps on the surroundings of the sites.
- A "forecast" function to predict the episodes of bad smells according to weather forecast as well as events on site such as maintenance.
- A "diagnosis" function to model an odorous event knowing the circumstances (emission, weather conditions) leading to it for a better understanding of the mechanisms of transport and dilution in the ambient air.

BACKGROUND

Real-time dispersion models coupled to CFD models
The literature survey on real-time dispersions shows that the real-time simulation tools are based on very simplified models of dispersion of particles, such as Gaussian or 2D models (Alhajraf S. *et al.*, 2005; Davakis E. *et al.*, 1998; Borysiewicz M.J. and Borysiewicz M.A., 2006; Sorensen J.H. *et al.*, 2007). Indeed a standard Gaussian or integral approach is very fast but tends to overestimate the concentrations and impact distances and is unable to predict correctly concentrations at close range.

On the other hand, more advanced models are able to take into account the specific configuration of a site in terms of topography and/or obstacles. More specifically, the three-dimensional models, based on the resolution of the equations of fluid dynamics (termed as Computational Fluid Dynamics (CFD) models), make it possible to simulate the gas emissions by taking into account the influence of the ground roughness and the nature of the local environment. (Hill R. *et al.*, 2007; Jenkinson P. *et al.*, 2007; Mazzoldi A. *et al.*, 2008). The drawback of CFD calculation is that it requires large CPU time. Therefore, the challenge of an innovative real-time numerical tool is to combine speed and precision for the calculation of the atmospheric flows and pollutant dispersion, in order to increase accuracy and dependability of real-time simulation results.

The methodology that will be described in this paper aims at providing such a numerical tool, by coupling the CFD models for local wind flows simulation with more classical Lagrangian models for dispersion modelling.

[2] SIAAP: Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne = the public body that manages sanitation systems around Paris.
[3] SYPROS : SYstème de PRévision des Odeurs du SIAAP = SIAAP odour forecasting system.

Wind modelling

A 3D CFD model, Fluidyn-PANEIA (Patil R. S. and Gupta S., 2005; Nicolas J. *et al.*, 2008) has been chosen to simulate the 3D wind field pattern on the WWTP, taking into account the details of the installations. This approach enables a precise simulation of the turbulence and flow around the buildings and near the ground; a crucial issue since short distance information is sought here.

Dispersion modelling

To obtain an odour real-time management system it is needed to couple the above quoted models (i.e. CFD model and Lagrangian puff model) to real-time adjustments of the source emission based on on-site continuous measurements. The so-called remapping process is then described in the following section.

THE REMAPPING: A NEW PROCESS FOR REAL-TIME ADJUSTMENT OF SOURCE EMISSION

Principle and methodology

The methodology chosen for the source definition is based on an iterative method of identification. The assumption is that for each condition of wind, there is at least one monitoring point for which the measured concentration comes only from one principal source. Knowing beforehand the dilution factors establishing a unique relationship between emitter and receiver (emission source and monitoring point respectively), the concentration of a source can be calculated from the measurement on this monitor point. This value then makes it possible to estimate the concentration of another source by means of another monitoring point for which the measured concentration comes from the contributions of two sources, one identified and one unknown. This iterative mechanism is then repeated as many times as possible. For each wind condition, two matrixes thus need to be created: the contribution matrix and the dilution matrix.

Details of the calculations

For any given meteorological condition, the transfer functions are defined using the following notation:

- *i*: index of source Si;
- *j*: index of sensor j;
- C_{Si}: concentration emitted by source S*i*;
- C_{Mj}: concentration measured by sensor *j*;
- X_{ij}: concentration measured at sensor *j* proceeding from source *i*.
- a_{ij}: contribution rate;
- b_{ij}: dilution rate;
- f_{ij}: transfer function = $a_{ij} * b_{ij}$

The concentration measured at sensor *j* is the result of the contribution of the emissions from sources *i* which impact that sensor. The contribution of these sources is designated a_{ij}. This contribution depends on the odorant flows emitted by these sources. The dilution rate between the concentration of TRS emitted by source S_i and sensor M_j is designated b_{ij}. This rate is independent of the odour flow emitted by source S_i. The theoretical calculations are illustrated on Figure .

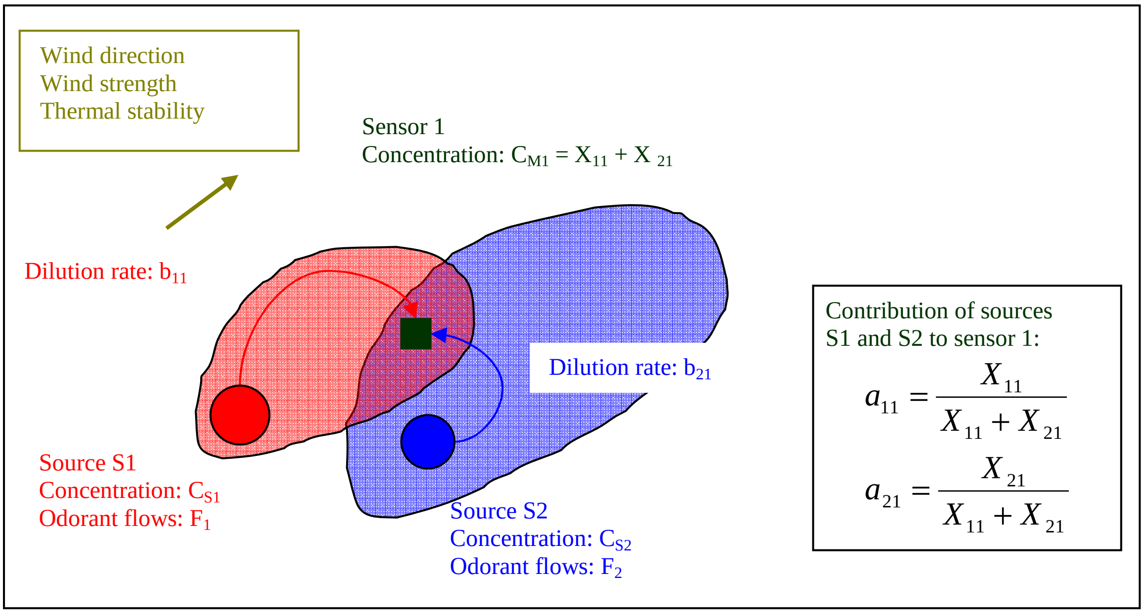

Figure 1: Coefficients of contribution and of dilution

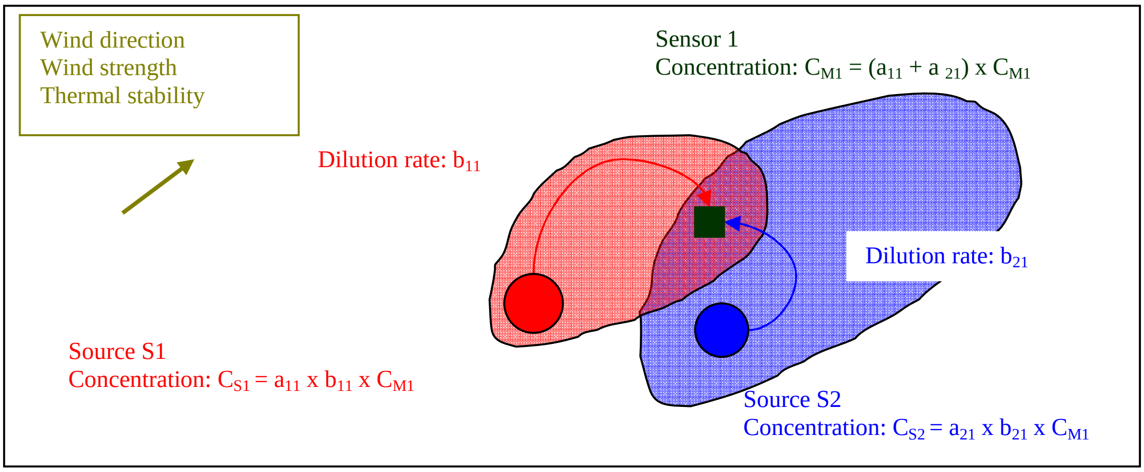

Figure 2: Example of transfer functions

The transfer function makes it possible to estimate the concentration emitted by the source or the sources which its emissions impact a given sensor, on the basis of the concentration measured by that sensor. For any given meteorological conditions, the transfer function f_{ij} between any source *i* and any sensor *j* corresponds to the product of the coefficient of contribution of source *i* to sensor *j* and the coefficient of dilution between that source *i* and that sensor *j* (see also Figure and equation 1*)*.

$$f_{ij} = a_{ij} \times b_{ij} \qquad (1)$$

CASE STUDY: APPLICATION TO THE SIAAP SITE OF SEINE AVAL

SYPROS presentation

This methodology has been integrated in an industrial functional way. The complete tool is called SYPROS and includes the following modules:

- An interface to set up and run simulations ;
- A numerical solver including a terrain digital model, a windfield database, a data acquisition system, an identification and interpolation wind module and a Lagrangian puff model for dispersion;
- An interface for results visualisation on the Intranet for the use of technical teams (for the real-time and the forecast functions) and on the Internet for the use of populations living nearby (for the forecast function).

Besides estimation in real-time of the nuisance to the nearby populations, such a tool can help manage the WWTP by helping in:

- Setting-up the rounds to check odours;
- Emitting alert boards;
- Understanding better the functioning of the site.

Real-time adjustment on the Seine aval site

Real-time adjustment assumptions

In the case of the implementation of SYPROS on the Seine aval site, the quasi real-time calculation line contains a file which, for all meteorological conditions in the wind field database, summarises:

- The matching table between the monitoring points impacted by the emissions in TRS from one or several facilities;
- The corresponding transfer functions.

These coefficients are established on the basis of theoretical transfer functions and a selection based upon their robustness. In fact, if the value of the theoretical transfer functions between any monitoring point and any facility are of the order of 10,000 and the concentrations measured at any sensor are low (linked to general environmental pollution rather than to the impact of any given facility), the use of the theoretical transfer function may lead to over-estimate the levels of TRS emitted by that facility and entail a considerable error on the estimation of the TRS plume. Thus, the theoretical transfer functions have been discarded under specific wind conditions:

- The winds do not blow on facility emitting TRS upwind of a monitoring point,
- The nearest facility to the monitoring point is at least about ten metres away (negligible diffusion phenomena).

Adjustment of the transfer functions

In order to check the TRS emission levels estimated by remapping, the transfer functions have been adjusted thanks to TRS readings at a monitoring point (M1), located in the neighbourhood of the WWTP. The periods during which the winds have blown from the WWTP area in the direction of the monitoring point M1 have been selected. For those periods, two sub-periods have been distinguished:

- Zero-concentration in TRS measured at point M1;
- Concentrations greater than 1 ppb measured at point M1.

Based on the identified sub-periods, calculations of atmospheric dispersion have been carried out in order to adjust the impact level of the WWTP area on the environment in terms of TRS. The transfer functions have been adjusted on the basis of this calibration.

These simulations were carried out with the real-time function and have made it possible to adjust the transfer functions used for the remapping according to the levels of impact in TRS on point M1.

The adjustment of the transfer functions for the “remapped” facilities has made it possible to readjust the default emission levels of certain other facilities (linearly).

CONCLUSION

A real time odour management tool, called SYPROS, has been implemented. It is an innovative system as it couples CFD model, Lagrangian model to real-time adjustments of the source emission based on on-site continuous measurements. To achieve these real-time adjustments the so-called remapping has been developed. The remapping process is based on an iterative method of identification and makes it possible to estimate a concentration emitted by an unknown source thanks to measurements at a sensor receiving contributions from two sources, one identified and one unknown. It is now possible to have a model that integrates a real-time adjustment thanks to dynamic continuous entry data. Being able to forecast and follow in real-time the odour dispersion around the WWTPs is a major improvement regarding neighbourhoods’ relationships as well as the site management and planning.

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